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Review Article

Clinical efficacy of periosteal pedicle graft as a barrier membrane in guided tissue regeneration: A systematic review and meta-analysis

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ABSTRACT

Background: The study aims to assess the clinical efficacy of periosteal pedicle graft (PPG) as a barrier membrane in guided tissue regeneration (GTR) for gingival recession, intrabony, and furcation defects.

Materials and Methods: Electronic and hand searches were performed to identify randomized controlled/clinical trials investigating GTR using PPG, with 6-month follow-up. Primary outcomes recorded: probing depth (PD), clinical attachment level (CAL), bone fill, recession depth (RD) reduction, percentage of mean root coverage, keratinized tissue width (KTW), and bone defect area (BDA).

Results: Thirteen articles were selected; 6 for recession, 2 for furcation, and 5 for intrabony. Meta-analysis was performed whenever possible, results expressed as pooled standardized mean differences (SMDs). In recession defects, the RD pooled SMD is 0.47 (95% confidence interval (CI) = [−0.50–1.44]), KTW pooled SMD is 1.30 (95% CI = [−0.30–2.91]), favoring PPG over the comparator. In furcation defects, PD pooled SMD is 1.12 (95% CI = [−2.77–0.52]), CAL pooled SMD is 0.71 (95% CI = [−1.09–2.50]), and bone fill pooled SMD is 0.67 (95% CI = [−3.34–4.69]) favoring PPG. In intrabony defects, PD pooled SMD is 0.54 (95% CI = [−2.12–1.04]), CAL pooled SMD is 0.23 (95% CI = [−1.13–0.68]), and BDA pooled SMD is 0.37 (95% CI = [−1.58–2.31]) favoring PPG. The results were not statistically significant.

Conclusion: The current evidence indicates that PPG constitutes a valid and reliable alternative to collagen barrier membranes for successful GTR.

Key Words: Collagen membrane, connective tissue graft, guided tissue regeneration, open flap debridement, periodontal regeneration, periosteal graft, periosteal pedicle graft

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INTRODUCTION

The management of tissue destruction caused by periodontitis has grown significantly as a result of continuous developments in the field of guided tissue regeneration (GTR) and guided bone regeneration (GBR). A membrane is utilized as a scaffold to establish a secure surgical microenvironment capable of inducing progenitor cell differentiation for GTR. These mat-like GTR/GBR membranes[1]

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strategically isolate the periodontal defect and function as a physical barrier to avoid gingival epithelial cell invasion.

To be used *in vivo*, these membranes must be biocompatible to allow integration with the host tissues without inducing inflammatory reactions, have appropriate biodegradability, sufficient strength to prevent membrane collapse and hold their barrier function.[2,3] There is considerable doubt that no unique biomaterial can effectively direct the simultaneous growth of several tissue types, particularly in pervasive periodontal defects.

The periosteum is a fragile tissue that covers the outer surface of bones comprising three zones; zone-1, commonly referred to as the cambium layer, is located closest to the bone and mostly consists of osteoblasts, osteoblast progenitor cells, and multipotent stem cells. In zone-2, also known as the matrix layer which makes the periosteum highly vascular contains fibroblasts, fibroblast progenitor cells, and a thick vascular plexus. Zone-3 is the outermost layer and is also referred to as the collagenous layer as it contains thick collagen fibers. The combination of zones 2 and 3 forms the fibrous layer. These periosteal stem cells and progenitor cells have the distinct potential to differentiate into a plethora of precursor cells in all age groups.[4,5] As broadly conceived, from a structural point of view, the periosteum is a bilayer membrane, and for regeneration, the preservation of this highly vascularized tissue is critical.[4,6] In addition, periosteal cells also yield vascular endothelial growth factor, which promotes angiogenesis and healing.[5-8] It is also believed that the periosteal layer is the one with maximum potential to regenerate lost periodontal tissues.[9,10] The periosteum is potentially a more appropriate bio-membrane that can be applied with minimal complications as a barrier membrane in GTR.

By exhibiting the aforementioned properties, the periosteum potentially reveals a highly viable alternative to a commercially available biomaterial in GTR. The use of the periosteum as a barrier membrane in periodontal regeneration dates back to studies[11] by Ellegaard *et al.*[9], Lekovik *et al.*,[8] and Kwan *et al.*,[12] in the 1970s–1990s that effectively treated gingival recessions, intrabony defects, and furcation defects using the periosteum harvested from the palate. This technique was further modified by Mahajan in 2009[13] where he described a periosteal pedicle graft (PPG) that acts as an autogenous graft for recession coverage. This provides continuous vascular supply to the graft over the denuded avascular root surface and stabilizes the blood clot that heals the surgical wound.

Various comparative studies were carried out to understand the potential of the PPG over other conventional methods such as connective tissue graft (CTG), coronally advanced flap (CAF) technique, and vestibular incision subperiosteal tunneling approach (VISTA) technique[14] for recession coverage. The PPG technique was also used and compared with resorbable collagen membranes for GTR procedures[15] for the management of furcation defects, intrabony defects, ridge augmentation,[16,17] and also maxillary alveolar clefts.[18] Open flap debridement (OFD) alone and with bone grafts, and resorbable collagen membranes were all reviewed with the PPG technique to understand the advantages and draw accurate comparisons.

Based on the hypothesis that the periosteum acts as a reservoir of stem cells,[10,17] also known as the "umbilical cord"[19] of bone, this systematic review and meta-analysis aims to establish the clinical efficacy of the PPG as a barrier membrane over other traditional resorbable collagen membranes in GTR for gingival recession, intrabony, and furcation defects.

MATERIALS AND METHODS

Study design and registration

The systematic review was based on and conducted in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) checklist.[20] The protocol was specified and registered with the International Prospective Register of Systematic Reviews (PROSPERO) (Registration number: CRD42022349058).

Focused PICO question

The focused question as proposed and prepared following the PICO framework[21] is:

Does PPG have a superior clinical efficacy when used as a barrier membrane in regenerative procedures for gingival recession, intrabony defects, and furcation defects over conventional methods?

Inclusion criteria

The PICO framework was applied as follows:

- Population/Participants (P) – Systemically healthy individuals with localized or generalized chronic

periodontitis with gingival recession or intrabony defect or furcation involvement
- Intervention, Exposure (I) – Use of PPG for the regeneration of periodontal defects; including gingival recession, intrabony, and furcation defects
- Comparators/Controls (C) – Any other traditional regeneration surgical procedures; (1) OFD with or without grafting, regeneration procedures for intrabony and furcation defects with a resorbable collagen membrane. (2) Periodontal plastic surgery such as subepithelial CTG, CAF, or any other root coverage procedures
- Outcomes (O).

Primary outcomes:
a. Probing depth (PD)
b. Clinical attachment level (CAL)
c. Bone fill
d. Recession depth (RD)
e. Percentage of mean root coverage
f. Keratinized tissue width (KTW)
g. Bone defect area (BDA).

Secondary outcomes:
a. Plaque index (PI)
b. Gingival index (GI).

Information sources and search strategy

Search strategies were designed, and searches were performed in electronic databases that included MEDLINE (PubMed), Scopus, HINARI, Google Scholar, and EBSCOhost using Mesh terms and other keywords [Supplementary Files] and manual searches were done using university library resources. Articles in the English language were preferred. Four periodontal journals, namely; *Journal of Clinical Periodontology, Journal of Periodontology, Journal of Periodontal Research, and International Journal of Periodontics and Restorative Dentistry* were identified as important to this review, and their electronic databases were searched manually. The search included all human randomized clinical trials (RCT) and controlled clinical trials conducted from the earliest records up to January 2023. Retrospective studies, cross-sectional studies, case series, and case reports were excluded. All cross-reference lists of the chosen articles were screened for extra literature that could meet the qualification criteria. A summary of the number of hits and articles chosen is tabulated [Table 1].

Table 1: Summary of number of hits and selected articles across the electronic databases

Search database	Number of articles	Articles in hit	Articles selected
Google Scholar	3047	59	12
Scopus	490	16	9
EBSCOhost	17	12	3
Hindawi	3452	254	4
PubMed	528	31	11
Embase	68	16	2

Data item

- RD: Distance from the cemento-enamel junction (CEJ) to the most apical part of the gingival margin
- KTW: Distance from the most apical part of the gingival margin to the mucogingival junction
- CAL: This is the distance measured from the CEJ to the base of the sulcus or pocket. The CEJ is the standard anatomical landmark to measure CAL pre- and post-periodontal therapy
- PD: Measured from the gingival margin to the base of the sulcus or base of the pocket. This distance helps quantify the disease severity by means of measurement and also helps to measure the loss of attachment
- Percentage of mean root coverage: The overall percentage of root coverage considering the reduction in RDs at different time intervals
- Bone fill: The feasibility of regeneration and attachment of periodontal ligament and alveolar bone after surgical treatment of periodontal defects. It is measured radiographically by measuring the distance from the CEJ to the base of the defect preoperatively and postoperatively. The difference in the two measurements denotes the bone fill for that site
- BDA:[22] Three distances were assessed linearly: (1) distance from CEJ to bone crest; (2) distance from CEJ to the bottom of the bony defect; and (3) distance from the bone crest to the bottom of the defect. Using graphics software, lines of linear measurements are connected to form a triangle on the image (JPEG format). The area of this triangle is calculated; b is the length of the base of the triangle; h is the height of the triangle, which denotes the length of a perpendicular from the vertex opposite the base of the triangle; and BDA = ½bh (in mm^2).
- GI:[23] For gingival condition assessment, distinguishing between the quality of the gingiva (the severity of the lesion) and the location (quantity) with respect to the four (buccal, mesial, distal, and lingual) areas that constitute for the total circumference of the marginal gingiva.

The index has four grades, ranging from mild to severe inflammation

- PI:[23] The distinction between the severity of the condition, and location of the soft debris aggregates. An index that matches the GI completely. PI has four grades from 0 to 3 indicating no plaque to abundant plaque in the sulcus.

Selection of studies and data synthesis

Two independent reviewers (S. I and S. S) screened the titles and abstracts, and then full-text articles were analyzed to decide whether the studies met the inclusion criteria, and any disagreement between reviewers was resolved through discussion. The study selection process was according to PRISMA guidelines.[24] The studies that fulfilled the inclusion and exclusion criteria were processed for data extraction. A standardized mean difference (SMD) with 95% confidence interval (CI) was calculated for continuous outcomes. A random effects model (Der Simonian-Laird method) was used. All statistical analyses were performed using RevMan 5.3 (Cochrane Collaboration, Software Update, Oxford, UK). The significance level was kept at $P < 0.05$.

Risk of bias assessment

Two review authors (S. I and S. S) independently and methodologically assessed the quality among included studies for seven domains plus an additional domain ("Assessing Risk of Bias in Included Studies, through Cochrane ROB-2 tool).[25] The overall risk for individual studies was assessed as low, moderate, or high risk based on domains and criteria.

Assessment of heterogeneity

The heterogeneity of the included studies was judged based on the following factors:

1. Type of defect (gingival recession, intrabony defect, and furcation defect)
2. Study design and evaluation period
3. Subject characteristics, defect inclusions
4. Surgical technique for periodontal regeneration.

The significance of any discrepancies in the pooled estimates of all the treatment effects from different trials was assessed by means of Cochranes's test for heterogeneity and the I^2 statistics. It describes the percentage of the total variation across studies that is due to heterogeneity rather than chance. Heterogeneity was considered statistically significant if $P < 0.1$. A guide to the interpretation of I^2 is given in the Cochrane Handbook.[26]

Investigation of publication bias

To test for the presence of publication bias, the relative symmetry of the individual study estimates was assessed around the overall estimates using Begg's funnel plot. A funnel plot (plot of the effect size versus standard error) was drawn. The asymmetry of the funnel plot may indicate publication bias.

RESULTS

Selection of studies

Preliminary screening was done after entering the search strategy. The primary screening comprised a cumulative total of 7534 articles, of which 372 were distinguished through the title and type of study. All these 372 articles were screened. After the exclusion of duplicate articles and only abstracts, 13 articles were considered appropriate for the review, as illustrated in the flowchart [Figure 1].

Data synthesis

The factors analyzed for the gingival recession were gingival RD, the width of keratinized gingiva, PD, and CAL and percentage of mean root coverage. The factors analyzed for intrabony defects and furcation defects were reduction in probing pocket depth (PPD), CAL, and bone fill and BDA. The mean values and standard deviation for each variable in each group were retrieved.

For the intergroup comparison, (PPG for recession coverage, intrabony defects, furcation defects) all data were organized in groups. A meta-analysis was carried out when it was feasible.

Study design and patient features

The age of the patients in the included studies ranges from 20 to 50 years, with a follow-up period ranging from 3 to 18 months, with an average of 6 months. All studies compared the use of PPG for GTR with other conventional or modified regeneration methods using resorbable collagen membrane for the treatment of gingival recession,[27,28] (Paramashivaiah *et al*.,[29])[30] Dandu *et al*.,[14])[31] furcation defects,[32,33] and intrabony defects[34-36] (Singhal *et al*.,[22])[37]) as shown in Table 2, respectively.

Sites and defect characteristics

All studies included patients who were healthy with no systemic conditions, well compliant, and willing for follow-ups as and when required.

For recession defects, Miller's Class I, Class II, and combined Class I and II with a clinical attachment loss of >3 mm were included.

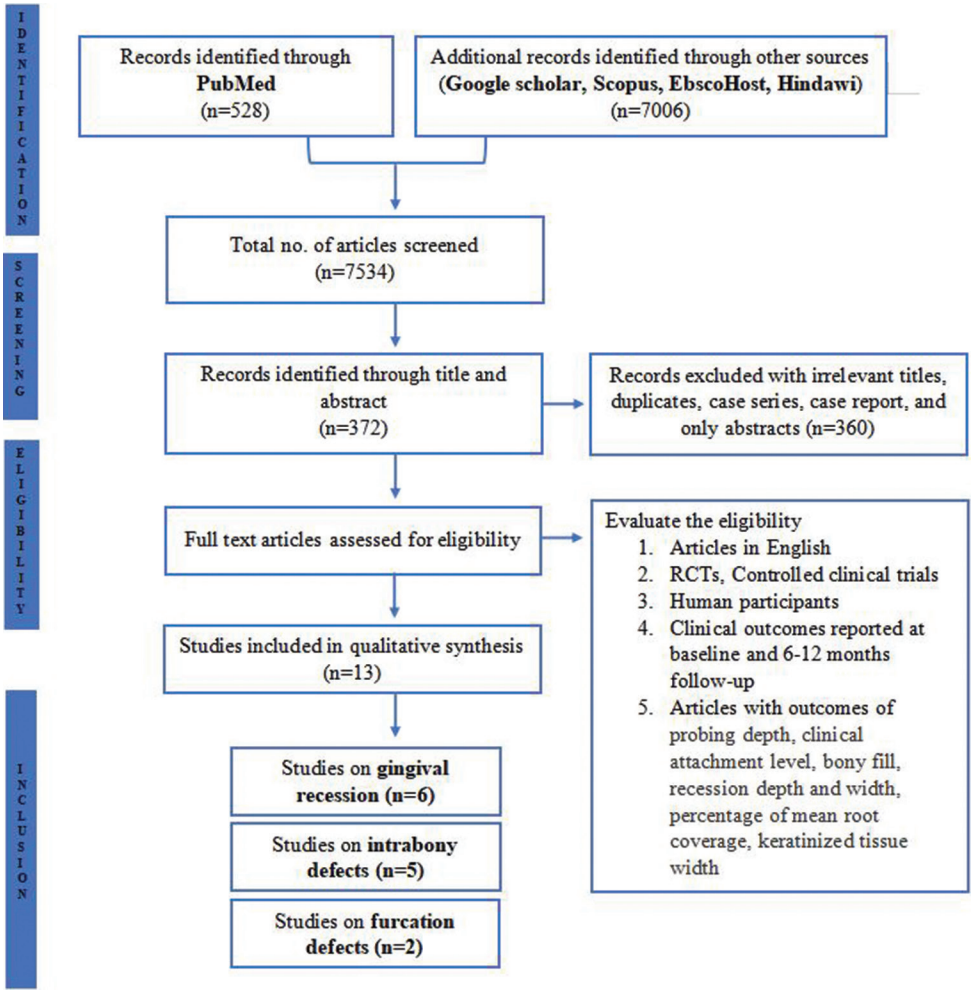

Figure 1: PRISMA flow chart of search strategy for this systematic review.

For furcation defects, Glickman's Grade II buccal furcation defects with a PPD of >5 mm were included.

For intrabony defects, deep two-/three-walled defects with a PPD of >5 mm were included.

Intervention

Gingival recession was surgically treated by PPG and compared with the conventional or modified methods such as modified CAF,[30] VISTA technique (Dandu *et al.*),[14] bilaminar technique,[27,31] or adjunct with low-level laser therapy (Paramashivaiah *et al.*[29]). Furcation defects and intrabony defects were treated by open flap debridement alone or with a periosteal pedicle graft used as a membrane[33-36] with a membrane and bone graft[32] (Singhal *et al.*,[22])[37]. Randomization for all the clinical trials was by either the coin toss method or a computer-assisted method was used.

Postoperative care

All studies for recession coverage, furcation defects, and intrabony defects mentioned standard postoperative instructions. Chemical plaque control was established by prescribing a chlorhexidine mouthwash of either 0.12%[27] (Hazzaa *et al.*,[32])[35-37] or 0.2% (Paramashivaiah *et al.*,[29])[30,33] (Dandu *et al.*,[14])[31] (Singhal *et al.*,[22])[34]. Analgesics prescribed were ibuprofen 400–600 mg[27] (Hazzaa *et al.*,[32] Dandu *et al.*,[14])[34,36] or nimesulide 100 mg[31,33] Antibiotic coverage was by amoxicillin 500 mg (Paramashivaiah *et al.*,[29])[33-36] or diclofenac sodium with serratiopeptidase (Paramashivaiah *et al.*,[29])[30] or a combination of amoxicillin-clavulanic acid (Hazzaa *et al.*[32]) or doxycycline 100 mg (Singhal *et al.*[22]). All patients were asked to refrain from any mechanical plaque control by brushing at the surgical site. Weekly follow-up visits were conducted for professional plaque control. Dietary habits were modified to soft food until initial healing.

Quality assessment

The quality assessment, performed by both reviewers (S. I and S. S), was based on the Cochrane Collaboration's

Table 2: Patient characteristics of all included randomised clinical trials

Author	Journal	Year	Defect, study design	Patient characteristics	Intervention	Control	Follow-up period	Author's conclusion
Bhavana *et al.*[28]	*Journal of Indian Society of Periodontology*	2023	Recession, RCT	60 patients, 30 in each group Patients aged 18–60 years Isolated Millers class I, II gingival recessions Systemically healthy patients	PPG	CAF + CTG	6 months	The PPG showed lower levels of pain and more consistent results with uneventful healing and hence may be a viable alternative to the well-known CTG
Elsayed *et al.*[27]	*Journal of Positive School Psychology*	2022	Recession, RCT	20 patients Miller's class I, II, III	PPG	CAF + CTG	6 months	PPG can be a promising alternative to SCTG for root coverage that can attain comparable root coverage outcomes
Paramashivaiah *et al.*[29]	*EC Dental Science*	2021	Recession, RCT	14 healthy patients Test group age - 39.8 years (all males) Control group age - 34 years (6 males and 1 female) Miller's class I, II	PPG + LLLT	PPG	6 months	The adjunct use of LLLT contributes significantly to higher output values and could give a higher predictability and stability
Nisha *et al.*[30]	*Journal of Oral Biology and Craniofacial Research*	2021	Recession, RCT	A total of 40 patients Mean age 38.2 years 22 women, 18 males 17 patients gave history of tobacco consumption Test - 64 sites, control - 59 sites	PPG	M-CAF	18 months	The use of PPG along with CAF is a viable treatment procedure in achieving optimal patient-based recession outcomes
Dandu *et al.*[14]	*International Journal of Periodontics Restorative Dentistry*	2016	Recession, RCT	15 patients 10 men and 5 women Mean age of 36.13 years Bilateral Miller class I or II 30 sites in total, 15 sites per group	VISTA	CAF + CTG	9 months	Within the limits of the study, it is reasonable to conclude that VISTA may be deemed a predictable, effective, minimally invasive, and viable alternative to the PPG technique for obtaining optimal patient-based outcomes
Mahajan *et al.*[31]	*Australian Dental Journal*	2012	Recession, RCT	10 males and 10 females Mean age 25.2 years Millers class I or II	PPG	CTG	12 months	Periosteum has immense potential to be used as a pedicle graft for the treatment of gingival recession defects and the results produced are better in terms of percent root coverage, predictability and patient satisfaction when compared to the connective tissue graft technique
Hazzaa *et al.*[32]	*Journal of International Academy of Periodontology*	2015	Furcation, RCT	26 patients 15 women and 11 men Mean age was 42.6 years Grade II buccal furcation involvement	PPG PPG + DFDBA	OFD	6 months	It represents also an alternative explanation for the potential efficacy of PPG in gingival wound healing. Meaningful im-provements in both clinical parameters and

Contd...

Table 2: Contd...

Author	Journal	Year	Defect, study design	Patient characteristics	Intervention	Control	Follow-up period	Author's conclusion
								features of gingival wound healing were revealed with the combination of PPG and DFDBA, supporting their adjunctive use in treatment of class II furcation defects
Verma *et al*.[33]	*Indian Journal of Dental Research*	2011	Furcation, RCT	11 pairs of patients 7 male and 5 female Mean age of 37.5±5.99 years Split-mouth approach Bilateral buccal Grade II furcation defects	PPG + OFD	OFD	6 months	The results of this study indicate that periosteal membranes were effective in the treatment of human mandibular buccal Grade II furcation defects. The future of regenerative therapy is indeed optimistic, due to the ongoing refinement of the variables in existing techniques, and also the utilization of new technology
Ghallab *et al*.[36]	*Egyptian Dental Journal*	2019	Intrabony, RCT	20 patients Age ranging from 35 to 50 years old CAL >5 mm PD >6 mm 2–3 walled defects	PPG + OFD	OFD + collagen membrane	6 months	It could be concluded from this study within its limitations that both treatment modalities could improve the clinical and radiographic outcomes and were effective in management of intrabony defects
Saimbi *et al*.[34]	*Journal of Indian Society of Periodontology*	2014	Intrabony, RCT	10 subjects 6 females and 4 males Age group 20–50 years Bilateral intrabony defects in relation to molars	PPG	OFD	3 months	Within the limitations of this study, it has been shown that periosteal membrane as GTR barrier can provide significantly greater improvements in pocket depth, CAL, and bone defect fill in intrabony defects compared to those treated by the open flap debridement procedure alone. It can be concluded from the present study that autogenous periosteal membrane as a barrier membrane is an effective GTR technique
Singhal *et al*.[22]	*Journal of Periodontology*	2013	Intrabony, RCT	20 patients 12 males, 8 females 20–50 years old Chronic periodontitis, PD >5 mm 2–3 walled vertical defects	OFD + PPG + alloplast	OFD + PPG	6 months	Within the limitations of this study, it can be safely concluded that space provision adds to the regenerative potential of autogenous periosteum as a barrier membrane in 2-wall intrabony defects

Contd...

Table 2: Contd...

Author	Journal	Year	Defect, study design	Patient characteristics	Intervention	Control	Follow-up period	Author's conclusion
Gamal *et al*.[35]	*Journal of Periodontology*	2011	Intrabony, RCT	15 patients Nonsmoking patients 13 males and 2 females aged 25–45 years at (mean age: 38.2–4.5) Severe chronic periodontitis, PD >6 mm, CAL >4 mm Bilateral defects	PPG	OFD	9 months	Periosteal coverage of periodontal defects is not associated with a significant increase in PDGF-BB levels. This finding suggests that physiologically, growth factors should not exceed certain levels even if one supplies defects with an additional number of exogenous cells
Paolantonio *et al*.[37]	*Journal of Periodontology*	2010	Intrabony, RCT	42 patients 20 males, 22 females Aged from 38 to 64 years (mean age, 48–12 years) Nonsmokers Systemically healthy and not taking any medications	OFD + PPG + autograft	OFD + collagen membrane OFD alone	12 months	Within the limitations of this study, we have shown that both the GTR and the combined regenerative procedures can provide significantly greater improvements in PD, CAL, and bone level in unfavorable intrabony defects compared to those treated by the OFD procedure alone. In particular, sites belonging to the combined approach showed greater bone gain compared to both the OFD and the GTR groups

OFD: Open flap debridement; PPG: Periosteal pedicle graft; RCT: Randomised clinical trial; PD: Probing depth; CAL: Clinical attachment level; DFDBA: Demineralized freeze-dried bone allograft; VISTA: Vestibular incision subperiosteal tunneling approach; CAF: Coronally advanced flap; LLLT: Low-level laser therapy; SCTG: Subepithelial connective tissue graft; GTR: Guided tissue regeneration

tool for assessing the ROB. All the included studies were largely comparable in methodological quality. All the included studies had a moderate to high ROB with all the respective domains. The highest ROB was seen for selective reporting (reporting bias) followed by random sequence generation (selection bias), allocation concealment (selection bias), and blinding of participants and personnel (performance bias). Among the included studies, Elsayed *et al*.[27] in 2022 showed the highest ROB while the lowest ROB was seen for Mahajan *et al*. in 2012[31] followed by Verma *et al*. in 2011.[33] Domains of other bias followed by blinding of outcome assessment (detection bias) and incomplete outcome data (attrition bias) were observed to have the lowest ROB in the included studies. The results of the bias assessment of the included studies through the Cochrane ROB-2 tool are presented in Figures 2 and 3.

Outcomes measured

Periosteal pedicle graft in recession defects

Primary outcomes

a. RD: Five studies contained data on 156 participants, of whom, (n = 78) participants were treated by PPG and (n = 78) patients were by other conventional procedures, as shown in Figure 4. The pooled standard mean difference is 0.47 (95% CI = [−0.50–1.44]). This signifies that the decrease in gingival RD on average is 0.47 times more with PPG, but this difference is not statistically significant (P = 0.35). The I^2 is 86%, suggesting considerable high heterogeneity
b. KTW: Four studies contained data on 126 participants, of whom (n = 63) participants were treated by PPG and (n = 63) patients were by other conventional procedures, as shown in Figure 5. the pooled standard mean difference is 1.30 (95% CI = [−0.30–2.91]). This signifies an increase in the width of keratinized gingiva on average is 1.30 times more with PPG, but this difference is not statistically significant (P = 0.11). However, the I^2 is 93%, suggesting considerable high heterogeneity
c. CAL: Five studies contained data on 156 participants, of whom (n = 78) participants were treated by PPG and (n = 78) patients were by other conventional procedures, as shown in Figure 6. the

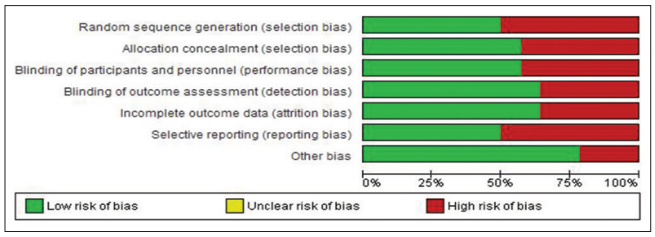

Figure 2: Risk of bias graph: Review authors' judgments about each risk of bias item presented as percentages across all included studies.

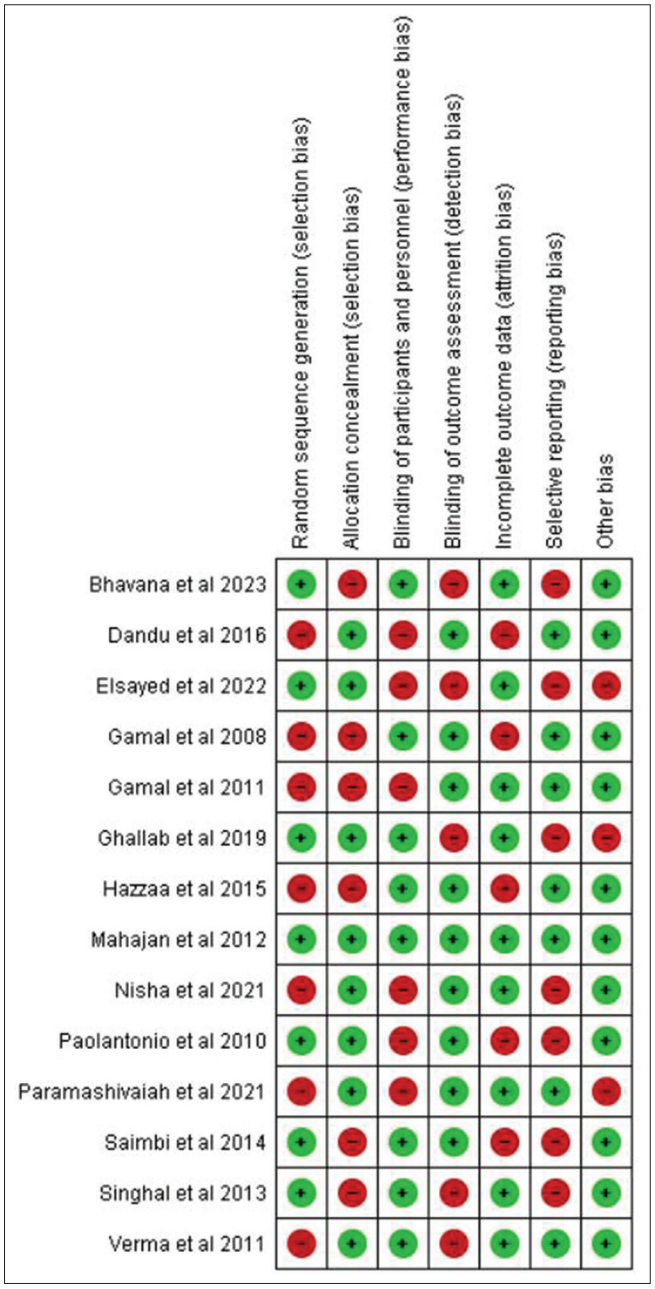

Figure 3: Risk of bias summary: Review authors' judgments about each risk of bias item for each included study.

pooled standard mean difference is 0.12 (95% CI = [−0.58–0.34]). This signifies that the increase in CAL on average is 0.12 times more with the conventional procedures, but this difference is not statistically significant (P = 0.611). The I^2 is 47% suggesting considerable moderate heterogeneity

d. PD: Five studies contained data on 156 participants, of whom (n = 78) participants were treated by PPG and (n = 78) patients were by other conventional procedures, as shown in Figure 7. the pooled standard mean difference is 0.16 (95% CI = [−0.57–0.24]). This signifies that a decrease in PD on average is 0.16 times greater by conventional procedure but this difference is not statistically significant (P = 0.43). The I^2 is 35%, suggesting considerable moderate heterogeneity
e. Percentage of mean root coverage: Only three studies reported the percentage of mean root coverage. Two studies compared PPG with SCTG where one study showed coverage of 85.74 ± 13.95% in the PPG group while SCTG showed 92.78 ± 10.93% at 6 months, indicating that the control was better,[27] while the other study had a 92.6% in the PPG group and 88.5% in the SCTG group[31] at 12 months. The third study reported a mean root coverage of 71.84 ± 19.25% in the PPG group when compared with 87.37 ± 17.78% in the VISTA group (Dandu *et al.*[14]), indicating that the VISTA technique was superior when compared to PPG.

Secondary outcomes

a. PI: Two studies reported significant reductions in the PI. Nisha and Shashikumar[30] recorded the reduction in PI as 0.67 ± 0.23–0.23 ± 0.18 at 3 months in the PPG group, while in the control group, the scores reduced from 0.63 ± 0.14–0.21 ± 0.13 at 3 months. The second study reporting the PI score was by Paramashivaiah *et al.*,[29] where the PPG group showed a reduction from 0.85 ± 0.28-0 ± 0.1 and the control group from 0.74 ± 0.32 to 0, at 3 months. Although a significant improvement was noted, the intergroup comparisons were not significant for both studies ($P < 0.05$)
b. GI: The same two studies reported GI scores. Nisha and Shashikumar[30] reported a reduction for the PPG group from 0.01 ± 0.01 to 0.02 ± 0.01 and from 0.02 ± 0.01 to 0.02 ± 0.02 for the control group at 18 months. Paramashivaiah *et al.*[29] reported a reduction from 1.0 ± 0 to 0.02 ± 0.05 for the PPG group and from 1.0 ± 0 to 0 for the control group at 6 months. The intergroup comparisons were not significant for both studies ($P < 0.05$).

Periosteal pedicle graft in furcation defects

Primary outcomes

a. PD: Two studies contained data on 44 participants, of whom (n = 22) participants were treated by PPG and (n = 22) patients were by other conventional procedures. As shown in Figure 8, the pooled standard mean difference is 1.12 (95% CI = [−2.77–0.52]). This signifies that the reduction in PD was on average 1.12 times greater in the PPG group, but this difference is not statistically significant (P = 0.18). The I^2 is 82%, suggesting considerable heterogeneity

b. CAL: Two studies contained data on 76 participants, of whom (n = 38) participants were treated by PPG and (n = 38) patients were by other conventional procedures, as shown in Figure 9. the pooled standard mean difference is 0.71 (95% CI = [−1.09–2.50]). This signifies that

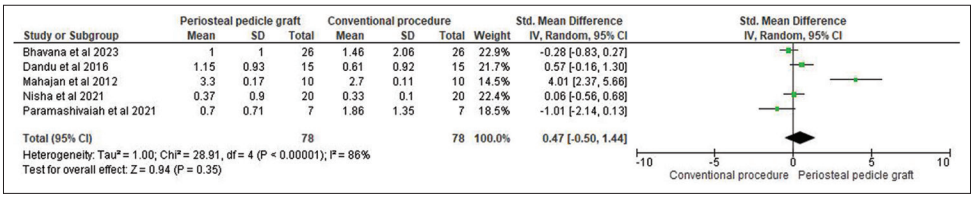

Figure 4: Forest plot showing periosteal pedicle graft for recession coverage with other procedures for the decrease in gingival recession depth.

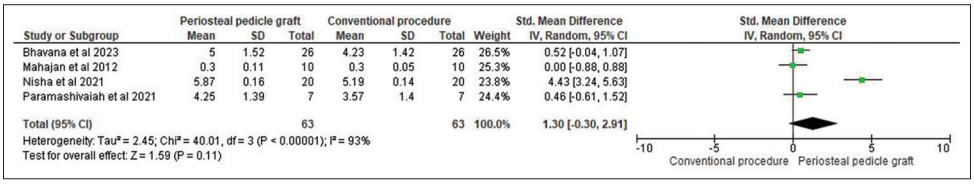

Figure 5: Forest plot showing periosteal pedicle graft for recession coverage with other conventional procedures for increase in width of keratinized gingiva.

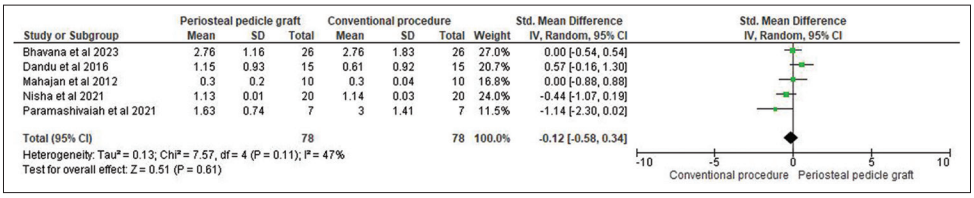

Figure 6: Forest plot showing periosteal pedicle graft for recession coverage with other conventional procedures for an increase in clinical attachment level.

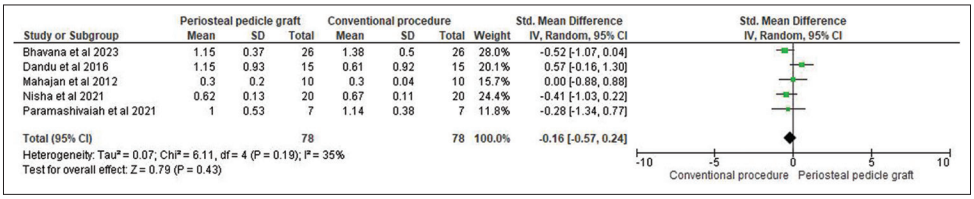

Figure 7: Forest plot showing periosteal pedicle graft for recession coverage with other conventional procedures for a decrease in probing depth.

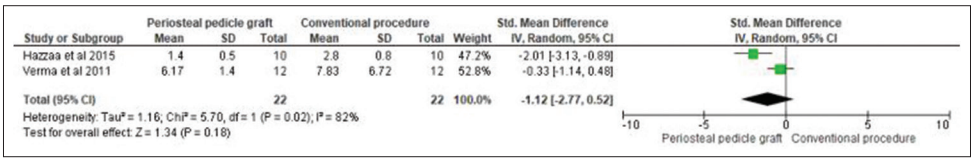

Figure 8: Forest plot showing periosteal pedicle graft for furcation defects with other conventional procedures for a reduction in probing depth.

the increase in CAL on average is 0.71 times greater with the PPG, but this difference is not statistically significant (P = 0.44). The I^2 is 92%, suggesting considerable heterogeneity

c. Bone fill: Two studies contained data on 76 participants, of whom (n = 38) participants were treated with PPG and (n = 38) patients were by other conventional procedures, as shown in Figure 10. the pooled standard mean difference is 0.67 (95% CI = [−3.34–4.69]) and the pooled estimates favor PPG. This signifies that the bone fill on average is 0.67 times greater with the PPG, but this difference is not statistically significant (P = 0.74). The I^2 is 97%, suggesting considerable heterogeneity.

Secondary outcomes

a. GI: The mean GI was measured only in one[33] of two studies. The PPG group measured a reduction in the score from 1.58 ± 0.33 to 0.92 ± 0.33 and for the control group, from 1.67 ± 0.49 to 0.92 ± 0.33 at 6 months post-treatment. Although a significant reduction was noted for both groups, the intergroup comparisons were not significant (P < 0.05).

Periosteal pedicle graft in intrabony defects

Primary outcomes

a. PD: Three studies contained data on 62 participants, of which (n = 31 each) in the PPG group and conventional approach group, as shown in Figure 11. the pooled standard mean difference is 0.54 (95% CI = [−2.12–1.04]). This signifies that the decrease in PD on average is 0.54 times greater with the use of the PPG, but this difference is not statistically significant (P = 0.51). The I^2 is 87%, suggesting considerable heterogeneity

b. CAL: Three studies containing data on 62 participants, with (n = 31) in either the PPG group or the other procedure group were evaluated in terms of an increase in CAL, as shown in Figure 12. the pooled standard mean difference is 0.23 (95% CI = [−1.13–0.68]). This signifies that the increase in CAL on average is 0.23 times greater with the PPG, but this difference is not statistically significant (P = 0.62). The I^2 is 66%, suggesting substantial heterogeneity

c. BDA: Two studies contained data on 32 participants, with (n = 16) in either the PPG group or the other procedures group were evaluated in terms of reduction of the BDA. One study[35] did not provide the data for BDA and was hence excluded from the meta-analysis, as shown in Figure 13. the pooled standard mean difference is 0.37 (95% CI = [−1.58–2.31]). This signifies that the reduction of the BDA on average is 0.37 times more by PPG but this difference is not statistically

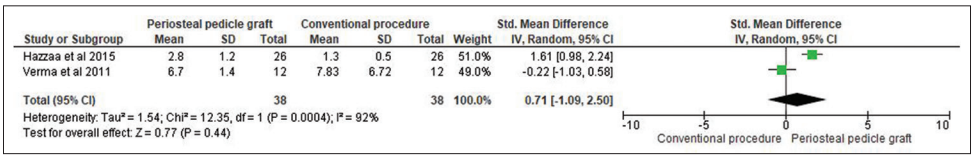

Figure 9: Forest plot showing periosteal pedicle graft for furcation defects with other conventional procedures for increase in clinical attachment level.

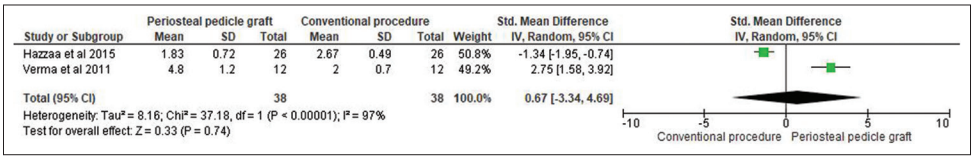

Figure 10: Forest plot showing periosteal pedicle graft for furcation defects with other conventional procedures for impact on bone fill.

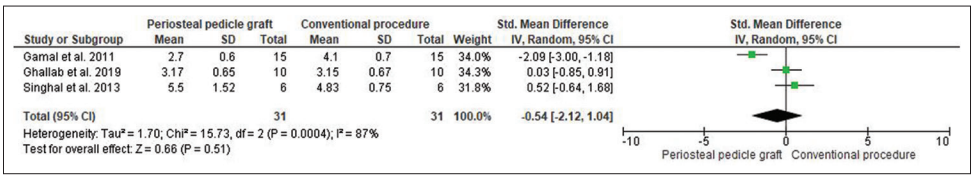

Figure 11: Forest plot showing periosteal pedicle graft for intrabony defects with other conventional procedures for decrease in probing depth.

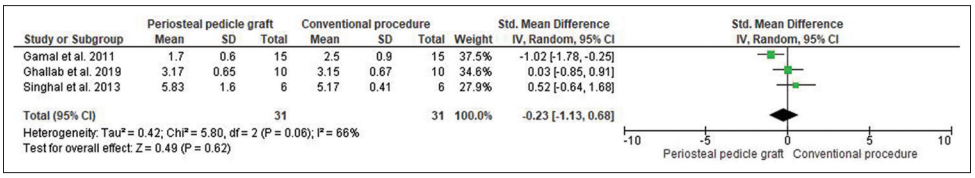

Figure 12: Forest plot showing periosteal pedicle graft for intrabony defects with other conventional procedures for an increase in CAL.

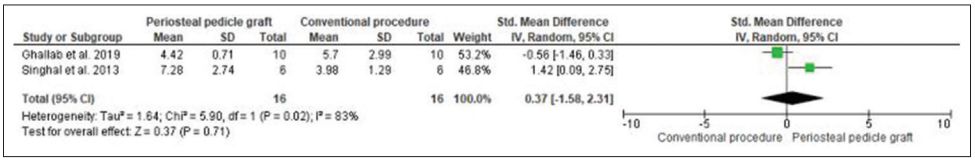

Figure 13: Forest plot showing periosteal pedicle graft for intrabony defects with other conventional procedures for impact on bone defect area.

significant (P = 0.71). The I^2 is 83%, suggesting considerable heterogeneity.

Secondary outcomes

a. PI: Only two studies reported a PI score. Ghallab *et al.*[36] noted a reduction in the PI scores from 2.50 ± 0.55 to 0.50 ± 0.53 for the PPG group while for the control group, the PI scores increased from 2.01 ± 0.46 to 0.62 ± 0.25 in the control group at 6 months. Similarly, Gamal *et al.*[35] noted a change from 0.3 ± 0.3 to 0.5 ± 0.7 in the test group and from 0.5 ± 0.2 to 0.7 ± 0.5 in the control group. A significant change was noted for both groups, but the intergroup comparisons were not significant ($P < 0.05$)
b. GI: One study by Ghallab *et al.*[36] reported a GI index reduction from 2.67 ± 0.52 to 0.33 ± 0.52 in the PPG group and from 3 ± 0 to 0.40 ± 0.52 in the control group. A significant change was also noted by Gamal *et al.*[35] for the test group from 0.4 ± 0.2 to 0.9 ± 0.7, and from 0.2 ± 0.2 to 0.7 ± 0.6 for the control group. Intergroup comparisons did not record any statistical significance ($P < 0.05$).

Additional analysis/publication bias

The funnel plot shows a symmetric distribution with an absence of systematic heterogeneity of each study as compared to the standard error of individual studies, indicating an absence of publication bias [Figure 14]. However, the number of studies is low to make any conclusive statement on publication bias.

DISCUSSION

Through the years of research on GTR, various strategies have been experimented with to find the most efficient barrier to achieving successful regeneration excluding epithelial cells.[3,6] Periosteum vessels develop a new microcirculation where there has been an injury to the bone. The new bone is formed as the result of relative movements of the bone exerted on the periosteum by rearrangement of osteoblasts along the direction of tension release. The undifferentiated layer thus plays a crucial regulatory role in bone remodeling because of the delayed reaction and visible structural changes in the mid-zone that act as a buffer. This process of bone regeneration through the periosteum has been termed "osteodistraction" where there is an increase in the surrounding adjacent bone and tissue volume.[4,5]

This review demonstrates that PPG as a barrier membrane has given an equivalent outcome to comparators in terms of gingival RD, PD, and a significant gain in the KTW, root coverage, and CAL (Nisha *et al.*[30], Mahajan *et al.*[31], Paramashivaiah *et al.*[29], Dandu *et al.*[14], Bhavana *et al.*[28]). The use of PPG along with a CAF or with adjuncts such as low-level lasers,[29] platelet-rich plasma[38] or platelet-rich fibrin[39] and additional growth factors[35] have also been implied with better results and higher predictability for recession coverage. However, when the mean root coverage achieved was compared between PPG and CTG, it was in favor of PPG in one study[31] and favored CGT in another.[27] It could be cautiously interpreted that PPG is equally efficient as that of the existing "gold standard," i.e., CTG in recession management. Of all the included studies, only one article[30] discussed increase in gingival thickness (GT), and that favored PPG. It is also to be noted from our review that GT is an important

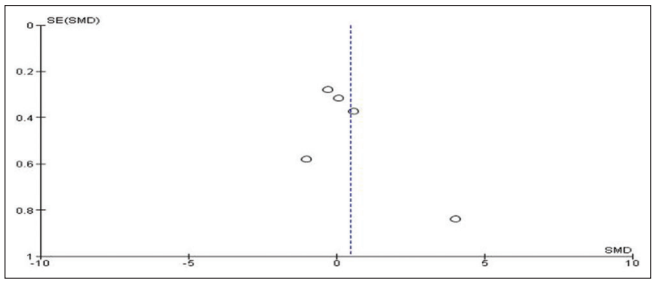

Figure 14: Begg's Funnel plot with 95% confidence intervals demonstrating symmetric distribution without systematic heterogeneity of individual studies.

parameter for predictable root coverage and should be considered an important variable in future research.

Furcation defects and intrabony defects have traditionally been treated with OFD or GBR with collagen membranes. The PPG technique used for recession coverage is slightly modified when used in cases of furcation or intrabony defects. The infected pocket lining causes destruction of the underlying periosteum so the periosteum is displaced from the mesial direction of the affected site with a distal pedicle, as described by Verma *et al*. for such defects.[33] From the results of this review, it could be inferred that the PPG used as a membrane with or without bone substitutes resulted in a reduction in PD, gain in CAL, and 0.67 times more bone fill in furcation defects. Hazzaa *et al*.[32] further evaluated histological sections and reported a well-organized collagen fiber arrangement and the presence of metabolically activated fibroblasts with the use of a combination of PPG and bone substitute. Though only two studies met our criteria, it could be interpreted that PPG enhanced the predictability of furcation management.

The treatment outcome for intrabony defects is affected largely by the morphology of the defect. Depending on the defect site and containability, the treatment of choice is always GTR (Murphy *et al*., 2003),[35,40] i.e., with a collagen membrane.[41] When using PPG for the treatment of intrabony defects, the PPG acts as a barrier or scaffold for GTR.[37] Among the included five studies, two studies[34,35] show a significant reduction in the PD and gain in CAL when a PPG is used, while Ghallab *et al*.[36] observed no significant difference in the parameters after OFD alone versus PPG. One study (Singhal *et al*.)[22] showed no significant difference in PD or gain in CAL when a PPG was combined with an alloplast. Paolantonio *et al*.[37] compared OFD alone, OFD with a collagen membrane, and OFD with a PPG combined with an autograft. This study showed that the PPG is on par with the GTR membrane when compared against OFD alone.

The periosteum stimulates bone formation in furcation and intrabony defects as it acts like a graft with sufficient soft tissue to avoid a collapse into the defect while maintaining the blood clot for early healing. When a bone graft (allograft or autograft) is added to this scenario,[32] the PPG acts as a GTR membrane similar to that of a resorbable collagen membrane that prevents epithelial downgrowth and bone graft resorption. Furthermore, the PPG will not cause any severe consequences on exposure, while collagen membrane exposure will have repercussions. The comparison of PPG with a nonresorbable membrane has not been evaluated in this study as the application of a nonresorbable membrane in GTR is justified in severe intrabony or furcation defects and in GBR for extensive bone augmentation. Hence, when rigid external support is required for the bone graft contained within the defect, non-resorbable membranes may be used since the defect itself does not have enough bony wall support. Besides, an additional surgery is required to remove the said membrane once an adequate bone fill or healing is achieved over a span of 6–12 months.[35,41] The comparison of PPG with non-resorbable membranes will be the same as comparing resorbable with nonresorbable membranes and since the rationale for both are different, this study did not include this comparison.

Radiographic bone fill seemed to be best when PPG was used with a bone graft. GTR with PPG membrane as a standalone therapy was closely followed as the next best option, and the least preferred was OFD alone.[34] Even histological studies have been conducted by Singhal *et al*.,[22] who used a combination of alloplasts as defect fillers, especially in containable defects (two/three-walled) and also in non-containable defects (one-walled) with PPG. The use of PPG had superior improvements in clinical outcomes as compared to conventional methods and also had the closest architecture to the normal periodontium (Steiner *et al*.).[17] However, both the studies included in this review have accounted only for linear measurements, whereas a cross-sectional assessment could have given a better evaluation of the bone fill outcome.

Although the PPG technique is less complicated than CTG harvesting and more effective than an OFD, its limitations are equally difficult to manage. Any damage to the periosteum while separating from the flap or alveolar bone will alter the formation of new bone, giving less optimized results. Careful handling of tissues is mandatory for controlled bleeding. This technique is contraindicated in patients with a thin gingival phenotype as it may cause a tear while reflecting a split-thickness flap. Once the periosteum is reflected, it may leave behind a "dead space" into which blood and inflammatory fluid can flow. In such cases, it may get complicated if the surgical site is in the canine-premolar area, where the blood accumulates and reaches the infraorbital areas causing a hematoma. Lengthy interventions may cause significant tissue damage and bleeding, leading to fluid buildup in interstitial spaces.[42]

Advanced periodontal defects such as Miller's Class III/IV recessions, Grade III furcation involvements, and one-walled intrabony defects are another dilemma that may be discussed. Depending on the prognosis and a thorough understanding of such defects, a strategy for treatment planning and management may be employed. The use of PPG may not be as applicable in such defects since there will be a limited amount of soft tissue and blood supply to create the necessary pedicle from the periosteum. In severe intrabony (one-walled) and furcation (Grade III) defects, no grafts can be accommodated in the site and hence an OFD and ressective surgery may be employed. For recession defects with interproximal bone loss (Miller's Class III/IV), the chances of achieving a complete root coverage are already questionable and hence two two-stage surgery approaches may be considered. Further clinical research is required to confirm the effectiveness of using PPG in such advanced defects.

According to our analysis, the PPG can be applied as an autogenous, pluripotent, and safe membrane for the mentioned defects. However, we notice several limitations in the current meta-analysis that should be declared. First of all, the number of RCTs and controlled clinical trials was less in number. Second, most of the included studies showed a moderate-to-high ROB. Third, high heterogeneity is seen due to differences in study design, patient selection methods, parameters recorded, defect morphologies, and follow-up periods. All the aforementioned limitations prevented us from drawing a definitive conclusion on the superiority of PPG as a gold standard over commercially available resorbable collagen barrier membranes. Nevertheless, the use of PPG as a membrane in regenerative approaches still gives promising results. There is a need for more randomized clinical trials with larger sample size and longer follow-ups to provide more conclusive evidence.

CONCLUSIONS

Within the limitations of this systematic review and meta-analysis, it can be interpreted that:

1. Although PPG is technique-sensitive, it avoids a second surgery (like in a non-resorbable collagen membrane)[41] and is abundant in pluripotent cells
2. PPG can be considered a living barrier membrane that displays regenerative properties along with barrier function in GTR when compared with other resorbable collagen membrane.

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Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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SUPPLEMENTARY FILE

Search strategy

RECESSION-

((((((((“autografts”[MeSH Terms]) OR (periosteal[All Fields]) AND (pedicle[All Fields]) AND (“surgical flaps”[MeSH Terms])))) AND (“gingival recession”[MeSH Terms]) OR (gingival recession[Text Word])) OR (marginal[All Fields]) AND (“tissues”[MeSH Terms]) OR (tissue[Text Word])) AND (recession[All Fields])) OR (“gingival recession”[MeSH Terms]) OR (gingival atrophy[Text Word])) OR (“furcation defects”[MeSH Terms]) OR (furcation defect[Text Word])) OR (furcation[All Fields]) AND involvement[All Fields])) OR (defect[All Fields]) OR (three[All Fields] AND walled[All Fields] AND defect[All Fields])) OR (two[All Fields]) AND (walled[All Fields]) AND (defect[All Fields])))

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INTRABONY-

(((((((laterally[All Fields]) AND (positioned[All Fields]) AND (“surgical flaps”[MeSH Terms]) OR (flap[Text Word])) OR (laterally[All Fields]) AND (sliding[All Fields]) AND (“surgical flaps”[MeSH Terms]) OR (flap[Text Word]))) AND (“abnormalities”[Subheading]) OR (defects[Text Word])) OR (three[All Fields]) AND (walled[All Fields]) AND (defect[All Fields])) OR (two[All Fields]) AND walled[All Fields]) AND (defect[All Fields])) OR (infrabony[All Fields]) AND (defect[All Fields])) OR (“bone and bones”[MeSH Terms]) OR (bone[Text Word])) OR (“guided tissue regeneration”[MeSH Terms]) OR (guided tissue regeneration[Text Word])))

FURCATION-

((((((periosteal pedicle graft) AND (regeneration)) AND (furcation)) AND (defect)) OR (intrabony)) OR (bone loss))

(((((((furcation) AND (periosteal)) AND (pedicle)) AND (graft)) OR (regeneration)) AND (bone loss)) AND (furcation defect)) AND (pedicle graft)))