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REVIEW ARTICLE

Effect of guided bone regeneration on immediately placed implants: Meta-analyses with at least 12 months follow up after functional loading

Bassam M. Kinaia[1,2] | Shahrdad Kazerani[1] | Samuel Korkis[1] | Omar Mario Masabni[1] | Maanas Shah[3] | Anthony L. Neely[1]

[1]Division of Graduate Periodontics, University of Detroit Mercy, Detroit Mercy Dental, Detroit, MI

[2]Private practice, Sterling Heights, MI

[3]Department of Periodontology, Hamdan Bin Mohammed College of Dental Medicine, Dubai, UAE

Correspondence
Bassam M. Kinaia, 2700 Martin Luther King Jr. Blvd. Division of Graduate Periodontics, University of Detroit Mercy, Detroit, MI 48208-2576.
Email: kinaiaperio@gmail.com

Abstract

Introduction: Immediate implant placement (IIP) into fresh extraction socket is a favorable treatment option. If successfully managed, it reduces the overall treatment time, and increases patient's satisfaction. Surgical and restorative factors affect IIP success rates. In this systematic review we evaluate the effect of guided bone regeneration (GBR) at the time of IIP on crestal bone level (CBL) changes after at least 12-months of functional loading.

Methods: Reviewers conducted an independent search of the National Center for Biotechnology Information PubMed, Medline, and the Cochrane Collaboration Library from 1966 to January 2017 following the inclusion criteria. A hand search of bibliographies of reviews and clinical trials related to IIP was also performed. This study looked into CBL changes around IIP primarily and further extracted the data to conduct three meta-analysis of "IIP using GBR versus IIP without GBR", "IIP using bone graft alone versus IIP using bone graft with membrane" and "IIP using GBR versus conventional implant placement" which were further subdivided to provide more detailed information for each. Four reviewers independently assessed the study data and methodologic quality using data extraction and assessment forms.

Results: The electronic search identified 714 potential studies and the hand search retrieved 55 studies. Crestal bone level (CBL) changes were determined in three meta-analyses. The results revealed a mean difference in CBL changes of 0.179 ± 0.174 mm in favor of IIP without GBR when compared with implant with GBR. However, IIP with bone graft and membrane showed better results when compared with IIP with bone graft alone [CBL changes of 0.532 ± 0.572 mm]. CBL preservation was noted in IIP with GBR versus conventional implant placement [CBL changes of -0.001 ± 0.049 mm].

Conclusions: Meta-analyses showed minimal difference in CBL around IIP with bone graft versus without bone graft and with IIP with GBR compared with conventional implant placement. However, IIP with bone graft and membrane reported better CBL preservation compared with IIP with bone graft alone. Nonetheless, these results should be interpreted with caution because of moderate heterogeneity between studies.

KEYWORDS
bone graft, crestal bone, dental implants, immediate implant, immediate loading, meta-analysis, systematic review

1 | INTRODUCTION

Dental implant placement timing post-extraction has varied historically.[1] Early studies recommended implant loading after 12 months to ensure adequate osseointegration.[1–4] Implant surface evolution with increased patient expectations to shorten treatment time led to the concept of immediate implant placement (IIP). Numerous protocols were suggested to categorize the time of implant placement[5,6] with immediate implants generally being placed in fresh extraction sockets. The first report of IIP was published in 1976 using a step thread tapered implant design, placed immediately into fresh extraction sockets.[7] Earlier studies suggested that IIP may preserve the integrity of the extraction socket in humans.[8–10] Despite the latter claim, the majority of the studies found that IIP alone cannot prevent bone loss after tooth extraction.[11–14] This is primarily due to the fact that crestal and facial bone resorb faster than the lingual plate post-extraction leading to compromised esthetics.[11–14] Such bone loss increases the risk of mid-facial recession, papillary loss and display of a gray hue of the underlying implants.[14–16]

Many factors affect the crestal bone level (CBL) around IIP's, including the number of remaining bony walls post-extraction,[17,18] the gap between implant and buccal bone and need for bone augmentation.[19,20] With regard to bone augmentation, different types of bone grafts and membranes have been employed around IIP.[21] Although the aforementioned factors play a significant role in CBL changes around IIP, the most recent reviews concentrated on IIP survival rates rather than systematically evaluating the results in a meta-analyses format.[20,22,23] The primary reason(s) for inability to perform a meta-analysis was high heterogeneity among the studies, hence, the main objective was to evaluate survival and success of IIP.[20,22,23] The current systematic review objectives are to analyze the effect of guided bone regeneration (GBR) around IIP in a meta-analysis format. Three meta-analyses as listed below were completed evaluating the effect of GBR on CBL changes after at least 12 months of functional loading:

- **I.** IIP using GBR versus IIP without GBR:
  - **I.a.** IIP with bone graft alone versus IIP without GBR.
  - **I.b.** IIP with bone graft and membrane versus IIP without GBR.
- **II.** IIP using bone graft alone versus IIP using bone graft with membrane.
- **III.** IIP using GBR versus conventional implant placement:
  - **III.a.** IIP with bone graft alone versus conventional implant placement.
  - **III.b.** IIP with bone graft and membrane versus conventional implant placement.

2 | METHODS

2.1 | Data sources and search

Two electronic databases, the "Preferred Reporting Items for Meta-Analysis (PRISMA) statement",[24] and "the Cochrane Collaboration recommendations"[25] were the basis for current meta-analyses. Data collection methodology fulfilled the criteria of the "Methodological Expectations of Cochrane Intervention Reviews (MECIR)".[26] Four reviewers (BMK, MS, SK, and SK) conducted an independent search of the National Center for Biotechnology Information PubMed, Medline, and the Cochrane Collaboration Library from 1966 to January 2017. Further, a hand search was conducted of bibliographies of reviews and clinical trials related to IIP. Disagreements between reviewers during data collection and quality assessment were resolved by discussion.

2.2 | Study selection and interventions

Publications had to report radiographic CBL changes and have the following criteria for inclusion: 1) published in English; 2) conducted on human subjects; 3) IIP with rough surface; 4) minimum of 12 months follow-up post-functional loading; 5) randomized or controlled clinical trials (RCTs, CCTs) or prospective clinical trials (Prosp CTs). Exclusion criteria were: 1) did not match the inclusion criteria; 2) reported data was on one piece or machine-surface implants; and 3) had missing data relevant to the systematic review.

The following search terminology was performed using Boolean operators: ((((((“dental implants”[MeSH Terms] OR (“dental”[All Fields] AND “implants”[All Fields]) OR “dental implants”[All Fields] OR (“dental”[All Fields] AND “implant”[All Fields]) OR “dental implant”[All

Fields]) AND immediate[All Fields]) OR ("bone transplantation"[MeSH Terms] OR ("bone"[All Fields] AND "transplantation"[All Fields]) OR "bone transplantation"[All Fields] OR ("bone"[All Fields] AND "graft"[All Fields]) OR "bone graft"[All Fields])) AND ("tooth extraction"[MeSH Terms] OR ("tooth"[All Fields] AND "extraction"[All Fields]) OR "tooth extraction"[All Fields])) AND ("regeneration"[MeSH Terms] OR "regeneration"[All Fields])) OR ("membranes"[MeSH Terms] OR "membranes"[All Fields] OR "membrane"[All Fields])) AND endosseous[All Fields] AND placement[All Fields] AND (("1966/01/01"[PDAT]: "2017/01/31"[PDAT]) AND "humans"[MeSH Terms] AND English[lang])

2.3 | Data extraction and collection

A data-extraction form was developed to collect the following study information: 1) author and publication year; 2) study type and randomization; 3) treatment groups; 5) patient and implant sample size; 5) crestal bone level change; 6) augmentation procedure and materials used; and 7) follow-up period. All data were screened and assessed independently by four reviewers (BMK, MS, SK, and SK) following the MECIR recommendations[26] and PRISMA[24] guidelines. Corresponding authors were contacted for complete ascertainment of data when relevant information was missing from a publication. The primary study outcome was CBL changes around IIP:

- **I.** IIP using GBR versus IIP without GBR:
  - **I.a.** IIP with bone graft alone versus IIP without GBR.
  - **I.b.** IIP with bone graft and membrane versus IIP without GBR.
- **II.** IIP using bone graft alone versus IIP using bone graft with membrane.
- **III.** IIP using GBR versus conventional implant placement:
  - **III.a.** IIP with bone graft alone versus conventional implant placement.
  - **III.b.** IIP with bone graft and membrane versus conventional implant placement.

Most studies used standardized periapical radiographs to assess the CBL changes[21,27–34] while one used non-standardized,[35] one study did not mention the technique they used,[34] and one study used panoramic radiograph.[36] The long-cone paralleling technique was used for the standardized technique. Analysis of the radiographs for each study was done by an independent, well-trained, and calibrated researcher.

2.4 | Statistical analysis

Data analysis was based on the mean CBL changes on the mesial and distal implant sites. Overall means for mesial and distal bone loss was calculated when reported separately using statistical software.*[37] Ninety-five percent confidence intervals (CI) and weighted mean differences (WMD) were calculated. Statistically significant differences were reported when $P < 0.05$. A statistical software program was used to perform meta-analyses which also produced forest plots.† Meta-analyses were estimated using a random-effects model. Test of null hypotheses was evaluated by a two-tailed Z-score. The 95% CIs were calculated around WMDs. Q statistic and I^2 measurement was used to assess heterogeneity. The Q statistic measures whether included studies measure the same effect, whereas the I^2 measure quantifies the percentage of variability in studies that cannot be ascribed to chance alone.[36] I^2 values ranged from 0 to100 with values of >75% indicating significant heterogeneity. In contrast, 0% for I^2 indicates no variability.[38]

2.5 | Quality assessment

Independent methodologic quality assessment was performed by four reviewers (BMK, MS, SK, and SK) based on the Cochrane Assessment of Allocation Concealment,[39] and the Jadad-Score Calculation.[40] The Cochrane Assessment of Allocation Concealment evaluated the validity and randomization of studies, assigning grades ranging from A to D. Grade A indicates no risk for bias, grade B is unclear risk for bias, and studies with grades C and D have high risk for bias. The Jadad method assigns a score ranging from 0 to 5 points. A score of 3 to 5 indicates a higher quality study, whereas studies with scores of 0 to 2 represent lower quality.

3 | RESULTS

The search results are summarized in Figure 1. The electronic searches identified 714 potential studies. An additional 55 studies were retrieved through a hand search of bibliographies of reviews and clinical trials for a total of 769 relevant publications. After review of abstracts and titles, 219 pertinent studies were selected for full-text review. Of the 219 studies, 113 were excluded because they failed to meet the inclusion criteria. The remaining 12 studies reported data that satisfied the initial inclusion criteria. A total of 12 studies had test and control groups allowing three meta-analyses to be conducted (Figure 1). Inter-observer agreement between reviewers was calculated using the Kappa statistic. Kappa was 0.98 and 0.92 for initial assessment of articles for full review (n = 57/769) and final inclusion in the meta-analyses (n = 12/57), respectively. The characteristics of the studies[21,27–36,41] included in the three meta-analyses are summarized in Table 1.

* Statistical thinking for managerial decisions: pooling the means, variances.

† Number Crunchers Statistical Software Program, NCSS, Kaysville, UT.

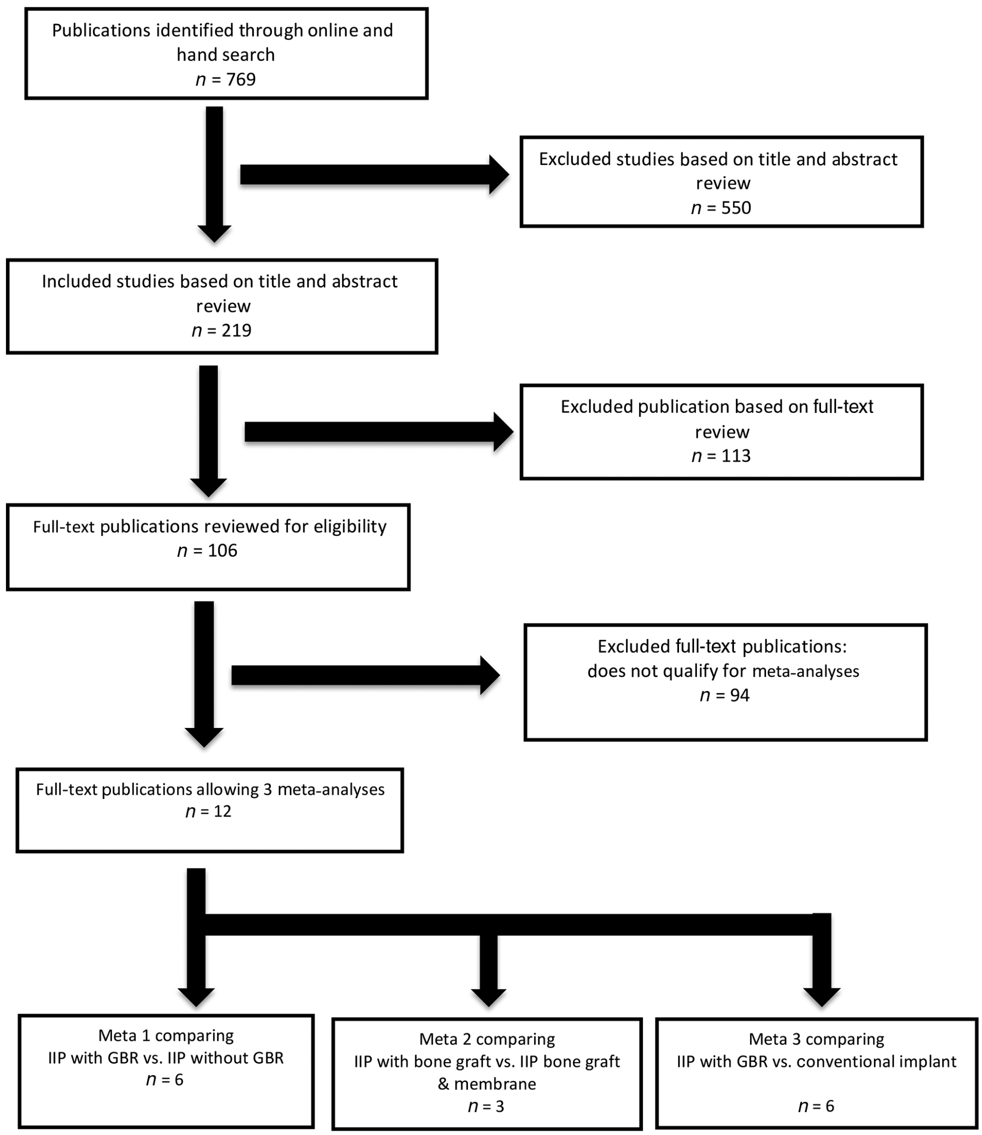

FIGURE 1 Flowchart for identification of publications according to PRISMA principles for systematic reviews

3.1 | Description of studies and methodologic quality

Of the 12 included studies, two were randomized clinical trials (RCTs),[27,29] four were retrospective studies[31,32,34,36] five were prospective clinical trials,[28,30,33,35,41] and one was a case series.[21] The RCTs scored high (grade A, and score of 4 and 5) according to the Cochrane Assessment of Allocation Concealment,[39] and the Jadad-Score Calculation,[40] while most of retrospective studies and prospective CTs scored lower (grade D, and score of 1 to 2). Two retrospective studies[31,32] and one prospective CT[33] scored high (grade B, and score of 3, respectively) (Table 1). The 12 studies included a total of 550 patients (ages 18–83 years) with a follow-up of 12 to 60 months. The studies had 931 implants with 594 placed immediately into extraction sockets (test) versus 337 implants placed conventionally in healed/native bone (control).

3.2 | Meta-Analyses

3.2.1 | I. IIP with guided bone regeneration versus IIP without guided bone regeneration

Six studies[21,28,30–32,35] compared IIP with GBR to implants without GBR. Two studies[30,32] reported CBL data at 12 months, one[35] at 24 months, two[28–31] at 36 months and one[35] at 60 months follow-up. A total of 168 were IIP with GBR while 212 were IIP without GBR. There was a mean difference in CBL changes of 0.179 mm [SD = 0.174 (95% CI, −0.162 to 0.520; $P = 0.304$)] in favor of IIP without GBR but the difference was not statistically or clinically significant. However, moderate heterogeneity was observed (I^2 = 59.62.10%) (Figure 2A). The six studies of IIP with GBR included IIP with bone graft only and IIP with bone graft and membrane versus IIP without GBR. Therefore, additional sub-analyses were conducted for IIP with bone graft versus

TABLE 1 Characteristics of the 12 studies included in the systematic review

Author, Year	*Study Design*	*Treatment Groups*	*Implant Location*	*Periodontal Biotype (Thick , Thin) - Detailed description*	*Presence of periodontal,periapical infection*	*Patient numbers*	*No. of Implants Placed*	*Mean Age of Patients (Range in years)*	*Measurement Technique*	*Implant Diameter x Length*	*Stability: Starting Torque in Ncm (ISQ values)*	*Flap (Fp) or Flapless (Fs)*	*Bone Graft, Membrane Type*	*Jumping Distance (mm)*	*Implant Survival Rates (%)*	*Tissue Level vs. Bone Level Stage Implant Placement*	*One Stage vs. Two Stage Implant Placement*	*Platform Switching vs Non-Platform Switching*	*Type of Prostheses (Insertion Time in Months)*	*IMMEDIATE Provisional*	*IMMEDIATE Loading*	*Final Evaluation Post Loading (in months)*	*Cochrane Allocation Concealment (grade)*	*Jadad score*
Pieri et al., 2009 [41]	PCT	IIP	9 Max and 15 Mand	NS	No	23	59	61.9 ± 7	Radiographically and clinically; PA, PAN, CT Standardized	Length: 10,11.5,13,15mm Width: 3.3,4mm	≥30Ncm	FP	Xeno and Auto graft when Jumping distance >2mm	NS	98.3%	Bone level	One stage	Ns	SR	All received fixed provisional SR within 48 to 72 h	All	19 (12-31 months)	D	1
		Delayed implant placement (control)					85		Resonance frequency measurement						98.8%									
Vandeweghe et al., 2012 [32]	Retrospective Multicenter Study	IIP with bone graft	Posteriors Max , Mand	NS	No	75	69 (17 IIP and bone graft)	58	Radiographically and Clinically; PA Standardized	Length: 7,9,11,13mm Width: 8,9,10mm (Max® Implant)	Ns	Ns	15 implants had Bio-Os 1 implant Auto 1 implant had combination of both	NS	89.7 % IL 95.8 % IIP	Ns	Ns	PS	N=29 immediate loading with fixed cross-arch bridges	Ns	29	14± 5.73 (6-34 months)	B	3
		Delayed implant placement					24								98.4 % DIL 95.8 % CIP						64			
Spinato et al., 2012 [31]	retrospective study	IIP + bone graft	Max Esthetic	Thick biotype	No	41	22	42.5	Radiographically and Clinically; PA Standardized	Length: (3.7,4.7)mm Width: (11.5,13,16)mm	≥35 Ncm	FS	None	2.25 ± 0.55 mm	100%	Bone level	One stage	Ns	6 months after placement.	Yes immediately or after 48 hours	No	Mean 32 months (Between 12-58 months)	B	2
		IIP No bone graft					23						Bone graft	2.03 ± 0.74 mm										
Block and Kent 1991 [21]	Prospective Study	IIP No defect No graft	Mand = 20, Max = 42	NS	No	34	27	Ns	Radiographically and clinically; PA and PAN Standardized	Length: 10, 13, 15mm	Ns	FP	None None	NS	100%	Bone level	Two stages	Ns	ST (n = 7), overdentures (n = 15), fixed, operator-removable prostheses (n = 12). after 3-6 months	No	No	24	D	1
		IIP Small defect<4mm No graft					6						Hydroxyapatite alone n=13 Or AAA n=6 (autolyzed antigen-extracted allogeneic) or AAA and auto iliac n=10		100%									
		IIP + large defect+ bone graft					29								93.1%									
Becker et al., 1999 [35]	Prospective Multicenter Study	Immediate implant	Max , Mand (not tooth specific)	NS	No	40	33 Max	55	Radiographically; PA Non-standardized	Ns	Ns	FP	No	NS	Max 93.9%	Ns	Two stages	Ns	Ns	No	No	Mean 36 months (1-5years)	C	2
							16 Mand								Mand 93.8%									
		Immediate implant with GBR				44	35 Max	50.5					Auto and NRM		Max 76.8%									
							20 Mand								Mand 83.8%									

(Continues)

TABLE 1 (Continued)

Pozzi and Mura 2016 [34]	Retrospective	Immediate implants	Max , Mand (not tooth specific)	NS	No	64	67	52.8	Radiographically and Clinically; PA, PAN, CT, CBCT Not mentioned	Ns	45 Ncm	FP	Xeno	NS	99.3%	Ns	Ns	PS	94 CR 54 SR	11	No	22.6 ± 8.7	D	1
		Delayed implants					81								100%					0				
Rodrigo et al., 2012 [33]	Prospective, Clinical Trial	Immediate implants	Max , Mand (not tooth specific)		No	22	34	59.3 (33-76)	Radiographically and Clinically; PA Standardized	Length: IP(10mm+10.5mm),D(11.7 mm+12mm) Width: 3.3mm(4IP,2D),4.1mm(23IP,31D),4.8mm(7IP,1D)	Achieved by resonance frequency analysis measurement	FP	Auto if gap <2mm Xeno if gap >2mm	1.24mm to 2.51mm	100%	Tissue level	One stage	NPS	NS	N=16	N=16	60	B	3
		Delayed implants					34							0	100%					N=12	N=12			
Peñarroch-Oltra et al., 2012 [36]	Retrospective study	IIP N=35	1st and 2nd max molars	16 buccal bone <2mm 19 buccal bone >2mm	No	70	35	54	PAN only	Length: (8.5,10,11.5,13) Width: (3.6,4.2,5.5)	Achieved by resonance frequency analysis measurement	FP	Auto alone or mixed with beta-tricalcium phosphate No membrane	12 implant >2mm 19 implants< 2mm	94.3%	Ns	One stage	NS	SR	NO	NO	12	D	1
		Delayed implants N=88					88								93.2%									
Chen et al., 2007 [28]	prospective controlled, clinical study		Max Esthetic	NS	No	10	10	45.2±10.1	Surgical re-entry at 0, 1, 2 and 3 yrs after prosthetic loading. Radiographically; PA Standardized	Ns	Ns	FP	bone graft	NS	100%	Bone level	One stage	NPS	NS	Yes	No	48±6	Grade D	2
		(ii) IIP + bone graft and resorbable membrane group (BGþM) N=10				10	10						bone graft and RM		100%									
		(iii) IIP + non-grafted control. N=10				10	10						non-grafted vs. control		100%									
De Rouck et al., 2009 [27]	RCT	IIP + immediate restoration group (TEST)	Max Esthetic	Thick biotype	No	24	24	55	Radiographically; PAs after provisionals at 3, 6, 12 months Clinically with acrylic stent Standardized	4.3mm x 16mm	>35	FP	Xeno	NS	96	Bone level	One stage	NPS	ST (6)	Yes	Yes	12	Grade A	5
		IIP + delayed restoration group (CONTROL)		Thick biotype		25	25	52		4.3mm x 16mm	>35	FP	Xeno with RM	NS	92	Bone level	Two Stage	NPS	ST (6)	No	No	12		
Vanden Bogaerde et al., 2005 [30]	PCT	IIP	Max and posterior mand	NS	No	19	50	55	Intraoral radiographs; Standardized Resonance frequency	13mm or 15mm in Maxilla 8.5 or 10 or 11.5 or 13mm in mandible	>30 Ncm	FP	N=33 Auto only N=4 Auto + RM	NS	100%	Bone Level	One stage	PS	fixed porcelain fused to gold alloy delivered after 6 months.	N=11 Immediate provisional N=11 within 4-7 days	yes	18	D	1
Linde-boom et al., 2006 [29]	RCT	IIP	Max Esthetic	NS	No	25	32	39.7 ± 14.5	Radiographically and Clinically; PA and PAN Standardized	NS	25 Ncm	FP	Auto	NS	92%	Bone level	Two-stage	NPS	NS	After 2 weeks	No	12	Grade A	4

Maxillary = Max; Mandibular = Mand; Controlled Clinical Trial = CCT; Prospective Clinical Trial = PCT; Randomized Clinical Trial = RCT; Retrospective Clinical Study = RCS; Clinical Study = CS; Not Specified = NS; Flap = FP; Flapless = FS; Months = mo; Resorbable Membrane = RM; Non-Resorbable Membrane = NRM; Platform Switching = PS, Non-Platform Switching = NPS; Autogenous Bone Graft = Auto; Allograft = Allo; Xenograft = Xeno; Single Tooth = ST; Immediate implant placement = IIP; Immediate loading = IL; Conventional implant placement = CIP; Delayed implant loading = DIL; Screw-retained = SR; Cement-retained = CR

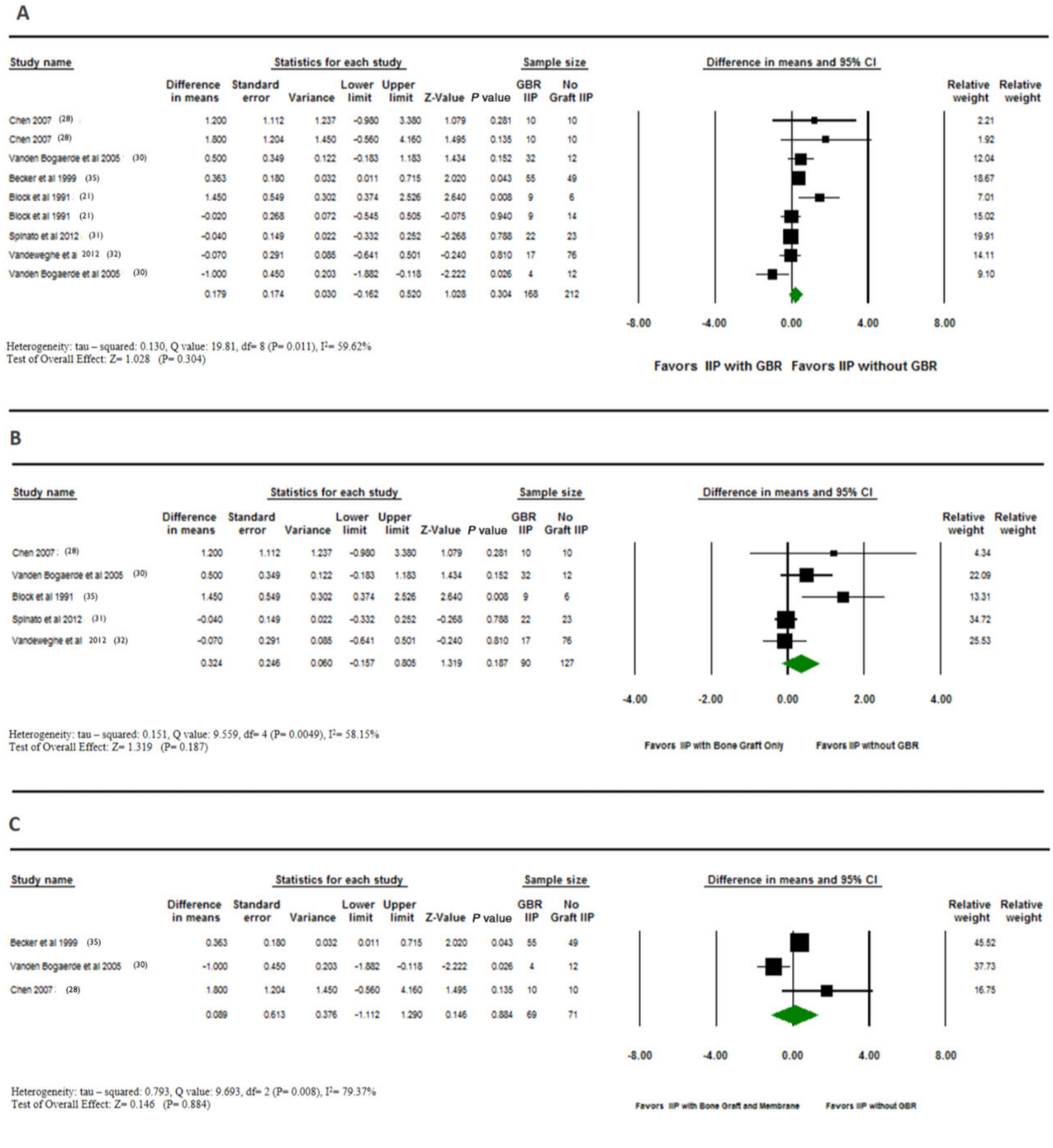

FIGURE 2 Meta I. Forest plot comparing CBL. **A**) IIP with GBR versus IIP without GBR. **B**) IIP with bone graft only vs IIP without GBR. **C**) IIP with bone graft and membrane versus IIP without GBR. df = degrees of freedom; I^2 = Heterogeneity

IIP without GBR (Meta I.a.) and for IIP with bone graft and membrane versus IIP without GBR (Meta I.b.).

I.a. IIP with GBR using bone graft only versus IIP without GBR

Five studies[21,28,30–32] compared IIP with bone graft only (90 implants) to IIP without GBR (127 implants). There was a non-significant mean difference in CBL of 0.324 mm [SD = 0.246 (95% CI, −0.157 to 0.805; $P = 0.187$)] in favor of IIP without GBR. The difference was not statistically significant with minimal clinical benefit and moderate heterogeneity among the studies ($I^2 = 58.15\%$) (Figure 2B).

I.b. IIP with bone graft and membrane versus IIP without guided bone regeneration

Three studies[28,30,35] compared IIP with bone graft and membrane (69 implants) to IIP without GBR (71 implants). There was a non-significant mean difference in CBL changes of 0.089 mm [SD = 0.613 (95% CI, −1.112 to 1.290; $P = 0.884$)]

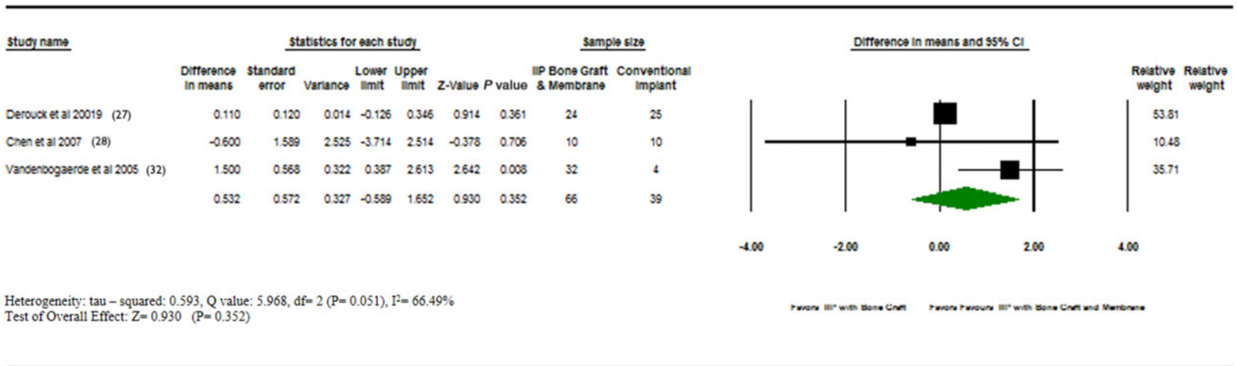

FIGURE 3 Meta II. Forest plot comparing CBL. IIP with bone graft versus IIP with bone graft and membrane. df = degrees of freedom; I^2 = Heterogeneity

in favor of IIP without GBR with high heterogeneity among the studies (I^2 = 79.37%) (Figure 2C).

3.3 | II. IIP with bone graft versus IIP with bone graft and membrane

Three studies[27,28,30] compared IIP with bone graft versus IIP with bone graft and membrane. Two studies[27,30] reported CBL data at 12 months and one[28] at 36 months follow-up period. A total of 66 were IIP with bone graft while 39 were IIP with bone graft and membrane. There was a non-significant mean difference in CBL changes of 0.532 mm [SD = 0.572 (95% CI, −0.589 to 1.652; P = 0.352)] in favor of IIP with bone graft and membrane. The heterogeneity among the studies was high (I^2 = 66.49%), indicating inadequate homogeneity between the studies (Figure 3).

3.4 | III. IIP with guided bone regeneration versus conventional implant placement

Six studies[29,32–34,36,41] compared IIP with GBR to conventional implants. All six studies[29,32–34,36,41] reported CBL data at the 12-month follow-up period. A total of 237 were IIP with GBR while 337 were conventional implants. There mean difference in CBL changes was – 0.001 mm [SD = 0.049 (95% CI, -0.098 to 0.095; P = 0.980)] in favor of IIP with GBR. The difference was not statistically significant. The heterogeneity was high among the studies (I^2 = 69.49%), indicating inadequate homogeneity between the studies (Figure 4A). The six studies of IIP with GBR included IIP with bone graft only and IIP with bone graft and membrane versus conventional implant placement. Therefore, additional sub-analyses were conducted for IIP with bone graft versus conventional implant placement (Meta 3.1) and for IIP with bone graft and membrane versus conventional implant placement (Meta 3.2).

3.4.1 | III.a. IIP with bone graft only versus conventional implant placement

Four studies[32–34,36] compared IIP with bone graft only to conventional implants reporting CBL data at 12-months. A total of 153 were IIP with bone graft alone while 227 were conventional implants. There was a significant mean difference in CBL changes of 0.093 mm [SD = 0.035 (95% CI, 0.024 to 0.161; P = 0.008)] in favor of conventional implants. The heterogeneity among the studies was zero (I^2 = 0.00%), indicating adequate homogeneity between the studies (Figure 4B).

3.4.2 | III.b. IIP with bone graft and membrane versus conventional implant placement

Two studies[29,41] compared IIP with bone graft and membrane to conventional implants reporting CBL changes at 12-months. A total of 84 were IIP with bone graft and membrane while 110 were conventional implants. There was a non-significant mean difference in CBL changes of −0.045 mm [SD = 0.055 (95% CI, −0.153 to 0.063; P = 0.412)] in favor of IIP with bone graft and membrane. However, high heterogeneity was observed (I^2 = 76.58%), indicating lack of consistency between studies. (Figure 4C).

4 | DISCUSSION

The objective of the current meta-analyses was to analyze CBL changes around immediately placed dental implants. Various surgical protocols such as the use of bone graft alone, membrane alone, bone graft and membrane can affect the CBL changes around IIP. Therefore, the aforementioned factors were analyzed in three meta-analyses.

4.1 | I. IIP with guided bone regeneration versus IIP without guided bone regeneration

The use of GBR influences the stability of bone levels around IIP. The current analyses evaluated CBL changes around IIP with versus without GBR. It was noteworthy that the results showed slightly better clinical CBL for IIP without GBR but was not statistically significant. Although the clinical difference was minimal, this could suggest that the gap between

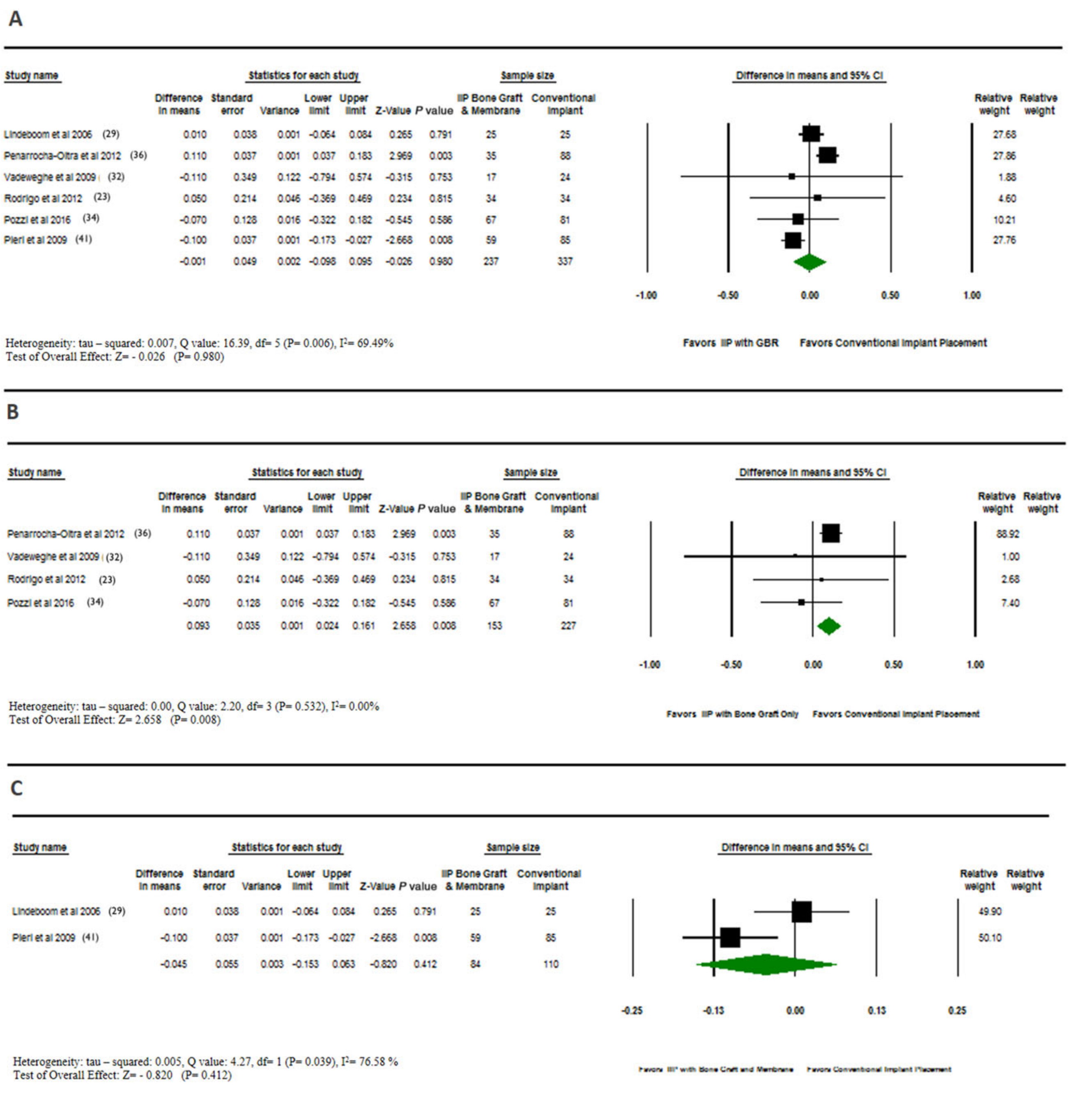

FIGURE 4 Meta III. Forest plot comparing CBL: **A**) IIP with GBR versus conventional implant placement. **B**) IIP with bone graft only versus conventional implant placement. **C**) IIP with bone graft and membrane versus conventional implant placement. df = degrees of freedom; I^2 = Heterogeneity

the implant surface and buccal bone may be filled with new bone without grafting. This explanation is rationale as the size of the gap significantly influenced the amount of new bone fill around IIP.[42] The current analyses showed better bone fill and implant success in small defects around IIP (overall survival = 93.8%). Block et al. showed 100% implant success in small defects (non-grafted) compared with 93% success in larger defects (grafted).[21] Similarly Becker had 93% in small versus 76% to 83% in large defects.[35] This is in agreement with what the literature cites. Botticelli et al. showed good bone fill for defects smaller than 3 mm (44 of 52 defects).[11] Further, Paolantonio showed spontaneous histological bone fill around IIP without GBR in defects of 2 mm or less.[43]

A recent review evaluated horizontal and vertical defect heights round IIP showing no difference in vertical CBL which is in agreement with the current analyses.[44] However, grafting around IIP preserved better horizontal ridge dimension compared with no grafting.[44] The latter systematic review reported the CBL changes vertically and horizontally but no analyses were performed. The current manuscript adds to the literature by comparing the results in a meta-analyses format. Therefore, it is reasonable to conclude that GBR around IIP is more important in larger defects while small defects can have adequate bone fill with or without GBR.

4.2 | II. IIP with bone graft versus IIP with bone graft and membrane

Adequate bone volume surrounding the implant is an important factor to maintain soft tissue stability and esthetics.[45,46] Peri-implant GBR enhances the bone stability and implant survival.[20] In the current meta-analyses, three studies were included using bone graft and membrane versus bone graft alone around IIP. The first study[27] had intact sockets, the second[28] exhibited dehiscence, and the third study[30] did not report buccal plate information. Despite presence of intact or dehisced sockets, the CBL was better preserved in IIP with bone graft and membrane compared with bone graft alone. The difference was 0.532 mm [SD = 0.572]. The latter finding is logical since membranes assist in complete graft containment without soft tissue down growth.[47] This is in agreement with a recent systematic review[44] where the use of membrane and bone graft showed less buccal plate resorption, good soft tissue exclusion and bone volume surrounding the implant. Further, another systematic review[48] (three trials; n = 98), showed evidence of an increased defect height reduction in favor of the membrane-covered IIP groups (Mean Difference: 6.25%, 95% CI: 1.67 to 10.82, P = 0.007; two trials) but the heterogeneity was high (I^2 = 79%). The current review reported a difference of 0.53 mm that is of clinical importance as mid-facial recession and papillary loss can be a possible complication associated with IIP.[45,46]

4.3 | III. IIP with guided bone regeneration versus conventional implant placement

The literature suggests that GBR around IIP can enhance the hard tissue response during the healing phase.[45,46] The current analyses showed negligible difference in CBL changes around IIP with GBR compared with conventional implant placement. The first sub-analyses (Figure 4B) reported a mean CBL difference of 0.093 mm [SD = 0.03] in favor of conventional implants while the second (Figure 4C) reported −0.045 mm [SD = 0.055] in favor of IIP with bone graft and membrane. While these results suggest that there is a minimal difference between IIP with GBR (−0.045 mm) and conventional implants (0.093 mm), the difference is not clinically or statistically significant. These results are in agreement with a recent systematic review showing a mean difference of −0.08 mm (95% Cl −0.18 to 0.01; P = 0.09).[49] This minimal difference between the groups should be interpreted with caution due to the high heterogeneity between studies.

5 | CONCLUSIONS

The results of this meta-analysis reported the following. 1) There is minimal difference in CBL between IIP with GBR versus IIP without GBR in small peri-implant spaces/defects with negligible clinical and statistically significant. 2) Clinically, better CBL is present around IIP using bone graft and membrane compared with IIP with bone graft alone but the difference was not statistically significant. 3) The small differences in CBL in favor of IIP with GBR compared with conventional implant placement could be meaningful in the esthetic zone. 4) The results should be interpreted with caution due to moderate heterogeneity among studies. This finding indicates that more uniform criteria are needed for methodologic designs of randomized clinical trials to improve homogeneity among studies and confidence in the results.

CONFLICT OF INTEREST AND SOURCE OF FUNDING STATEMENT

The authors declare no conflicts of interest. Data were gathered by BMK, SK, SK and MS and sent to a biostatistician for analysis. No author received monetary compensation for this manuscript.

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