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Efficacy of allogenic block graft for alveolar ridge augmentation for implant placement: a systematic review and meta-analysis

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ABSTRACT

Aim Augmentation procedures are done to overcome the atrophic ridges to provide an adequate bone volume for implant placement. Various grafting materials are used for the same. The purpose of the study was to evaluate the efficacy of allogenic block graft for alveolar ridge augmentation of the atrophic partial and/or complete edentulous jaw for implant placement.

Material and Methods Articles related to use of allogenic block graft for ridge augmentation and placement of implants were included. Risk of graft failure and implant failure was estimated at 95% confidence interval.

Results Initial literature search resulted in 1212 papers. Finally, 19 articles were included. Forest plot for the event graft failure, Cochran's Q was 17.978 and was significant (P=0.006). In the forest plot for the event implant failure, Cochran's Q was 14.098 and was also significant (P<0.001). The studies examined in this review provide evidence of successful alveolar ridge augmentation (98% to 100%) using block allografts (cortico-cancellous or cancellous) with high short-term (<5 years) implant survival rates (95% to 100%).

Conclusion Allogenic block graft for ridge augmentation has shown similar success with graft and implants placed compared to autogenous block graft & overcomes the drawbacks of autografts. Block allograft failures were mostly found in mandibular posterior. Standard length and diameter of the implants placed at the augmented sites had increased implant survival rate.

INTRODUCTION

The long-term survival of the dental implants depends on the quality and quantity of the bone available for implant placement (1). One of the most common problem being faced in implant placement is the atrophic edentulous sites, occurring due to periodontal disease, trauma or post-extraction resorption. Residual alveolar ridge defects are classified as horizontal, vertical, or combined defects, according to the main resorbed region. The classification helps the surgeon in better diagnosis and treatment planning (2).

Augmentation procedures are being done to overcome the atrophic ridges, so as to provide an adequate bone volume for implant placement (3). Various techniques to reconstruct and/or regenerate atrophic alveolar ridges are ridge split crest, bone block graft, biomaterials, distraction osteogenesis, and guided bone regeneration(G-BR) (1,4,9).

The autogenous bone has properties like osteogenesis, osteoinduction, and osteoconduction. It is considered as gold standard for grafting procedures and being used in both block and/or particulate form (10,11).Autogenous block graft has less treatment recommendations, due to reduced patient acceptance, the size/quantity of graft obtained from intraoral sites is limited. There is also morbidity associated with block grafts harvested from the retromolar or symphysis region in the form of soft tissue injury, nerve injury, wound dehiscence and infection (12,13).

Variety of bone substitute materials (BSM) are available

and categorised as allogenic, xenogenic and alloplastic.10Allogeneic block graft lacks many of the limitations of autogenous block graft especially the ones related to donor site along with availability of blocks in predefined configuration and also in cortico-cancellous composition (14).
Although studies included in a previous systematic review14 have shown successful implant placement following ridge augmentation with block allografts, the effectiveness and predictability of these grafts for ridge augmentation is still not clear. Till date there is no meta-analysis specifically on the use of allogenic block graft for ridge augmentation. So, the aim of the present systematic review and meta-analysis was to assess the efficacy of allogenic block graft for alveolar ridge augmentation of the atrophic partial and/or complete edentulous jaw for the implant placement.

MATERIALS AND METHODS

This systematic review was based on PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines (PROSPERO id: CRD42020165114) (15).

Focused questions

The PICO16 (population, intervention, comparison and outcome) strategy was used and the question focused was: "Does patients (P) with complete or partially edentulous atrophic ridges who undergone bone augmentation (horizontal and/or vertical) procedures using different allogenic block graft to place dental implants (I) exhibits difference in outcome (O) of block grafts and implant failures, compared (C) to other materials placed or no graft placed?".

Inclusion criteria

Randomised controlled clinical trials (RCT), controlled clinical trials (CCT), prospective studies, retrospective studies and case series on ridge augmentation procedures (horizontal and /or vertical) with allogenic block graft in partially and completely edentulous patients with atrophic maxilla and/or mandible. Additional inclusion criteria were: studies with a minimum of 5 or more patients with primary outcome to find the block grafts and implant failures were included. The studies where amount (width/height) of alveolar ridge gained through the augmentation procedure (radiographically or clinically measured) and mentioned the complications related to grafts and implants were also included.

Exclusion criteria

Animal studies, in vitro studies, numerical analysis, studies focusing on patient-centred outcomes or studies based on patients records/surveys/questionnaires or interviews, reviews and case reports were excluded.

Outcome measure

The primary outcome was to find out, the number of block graft and implants failed which were placed in the augmented sites. The secondary outcome was to find the adverse events such as infection, wound dehiscence and any block graft related complications.

Search strategies

A detailed electronic literature search of the article published in English language was undertaken in February 2021 on Medline/PubMed and Cochrane databases with no restriction on year of search (Tab. 1). The studies were screened and selected by three reviewers separately (R.G, R.C, and S.K.M). A hand search was done to identify other eligible studies by searching the references of the included studies and other published reviews. Journals related to implants were also searched, which included: Implant Dentistry, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Journal of Periodontology, Journal of Oral Implantology and International Journal of Oral and Maxillofacial Implants.

Selection of studies

Initially, duplicate articles were checked and removed, and then the titles and abstract of the remaining articles were screened for eligibility. Based on inclusion and exclusion criteria, complete texts of eligible articles were read. The level of agreement among the reviewers was analyzed using Kappa statistics (ƙ).

Data extraction

Data was extracted from each study under the following headings: author, year, type of study, study setting, number of patients and gender, location, type of ridge, number of defect sites, smoking/systemic diseases if reported, type of ridge augmentation, number and type of

Subject	(allogenic block graft OR allogenic block bone graft OR augmentation OR horizontal ridge augmentation OR vertical ridge augmentation OR maxillary ridge augmentation OR mandibular ridge augmentation OR dental implants OR oral implants [all fields])
Adjective	(clinical outcome OR radiographic outcome OR graft survival OR complications OR graft failure OR implant survival OR implant failure [all fields])

TABLE 1 Search terms for electronic database search

Reference	Study design	Centre	Number of patients (M/F)	Complete or partially edentulous	Jaw (region)	Number of defect sites	Smoking/ Systemic diseases	Type of ridge augmentation
Keith et al.(2006)20	Prospective	Multi-centre	73 (27/46)	Partially edentulous	Maxilla; mandible	82	n=2smokers; n=2menopause;n=1 psychiatricproblem; n=1 TMJ disorder	Horizontal and vertical
Contaretal. (2009)21	Prospective	University	15 (6/9)	Complete edentulous	Maxilla	Not reported	0	Horizontal
Peleg et al.(2010)22	Prospective	Private clinic	41 (14/27)	Partially edentulous	Maxilla; mandible	57	0	Horizontal and vertical
Nissan et al.(2011)23	Prospective	University	31 (11/20)	Partially edentulous	Maxilla (Anterior)	46	0	Horizontal and vertical
Nissan et al.(2011)24	Prospective	University	21(3/18)	Partially edentulous	Mandible (Posterior)	21	Not reported	Horizontal and vertical
Nissan et al.(2012)25	Prospective	University	40 (14/26)	Partially edentulous	Maxilla (Anterior)	Not reported	Not reported	Horizontal and vertical
Novell et al.(2012)26	Prospective	Private clinic	20 (7/13)	n=4complete edentulous; n=16 partially edentulous	Maxilla; mandible	Not reported	n= 2 former smoker;n=3 hypertensive; n=1 hyperparathyroidism; n=1 depression; n=1 parental drug addict	Horizontal andvertical
Krasny et al.(2015)27	Prospective	Private clinic	21 (6/15)	Partially edentulous	Maxilla; mandible	26	0	Horizontal and vertical
Dias et al.(2016)28	Prospective	University	12 (3/9)	Partially edentulous	Mandible	16	0	Horizontal and vertical
Schlee et al.(2014)29	Retrospective	Private clinic	31(8/23)	Partially edentulous	Maxilla; Mandible	Not reported	n=10 former smoker	Horizontal andvertical
daCosta et al.(2011)30	RCT	Hospital	10 (2/8)	Partially edentulous	Anterior maxilla	20	0	Horizontal
Amorfini et al. (2014)31	RCT	University	16	Partially edentulous	Mandible (Posterior)	32(n=16 test group; n=16 control group)	0	Horizontal and vertical
Leong et al.(2015)32	RCT	University	16 (10/6)	Partially edentulous	Mandible (Posterior)	19 (n=9 test group; n=10 control group)	0	Vertical
Deluiz et al.(2017)33	RCT	University	66 (14/52)	Both partial and complete edentulous cases	Maxilla	113	0	Horizontal
Tresguerres et al.(2019)34	RCT	University	28 (6/22)	Partially edentulous	Maxilla; mandible	Not reported	Smokers and low bone mineral density	Horizontal
Soltan et al.(2007)35	Case series	Private clinic	5 (1/4)	Partially edentulous	Maxilla	5	Not reported	Horizontal
Nissan et al.(2008)36	Case series	University	11 (2/9)	Partially edentulous	Maxillary anterior	11	0	Horizontal
Pendarvis et al.(2008)37	Case series	University	9 (4/5)	Partially edentulous	Maxilla; mandible	Not reported	0	Horizontal
Wallace et al. (2010)38	Case series	Private clinic	12 (2/10)	Partially edentulous	Maxilla (Posterior)	16	0	Horizontal

TABLE 2 Included articles-an overview

allogenic block grafts used, graft fixation, membrane if used along, any other graft material or growth factors used, bone augmentation achieved at baseline and the modality used for measurement, post-augmentation healing period, final bone gain/entry width, bone resorption/graft survival, histologic findings, failed block grafts with reason for failure, block graft related complications, number of implants placed, type of implant loading, fixation type, follow-up of implants, number of implant failures, survival rate of the loaded implant.

Quality assessment

The quality of study and risk of bias was assessed independently by two reviewers (R.G. and S.K.M). Newcastle-Ottawa scale (NOS) was used to assess the quality of the case control and cohort studies (17). A minimum of 5 years of follow-up was necessary to appropriately allow the analysis of the survival and success of implants (18). Any study with six or more points can be considered as of high quality. Cochrane collaboration's tool was used to assess the risk of bias of the RCTs and was based on four criteria: sequence generation, allocation concealment incomplete outcome data and blinding. A study was classified as: having low risk of bias, if it included all the criteria mentioned above; unclear risk of bias, if one of the above criteria was not included; high risk of bias, if two or more criteria were not included(19).

Data synthesis and meta-analysis

Meta-analysis was performed using statistical R software (2018, version 3.4, R Software Services INC, California, USA). Graft failure and implant failure were the dichotomous outcome measured and expressed in risk estimates and 95% confidence intervals (CIs). A fixed-effects (FE) model was used where statistically significant heterogeneity was detected and random-effects (RE) model was used to assess the significance of

Variables	Findings related to implants and block grafts
Gender distribution	
Males	136 (30.8%; n=18)
Females	305 (69.2%; n=18)
Jaw n (%)	
Maxilla	262 (68.2%; n=15)
Mandible	122 (31.8%; n=15)
Block graft	
Number of block graft placed	685 (n=18)
Block grafts failed	16 (2.33%; n=18)
Block complications	70 (10.21%; n=18)
Implants	
Implants placed	1134 (n=18)
Failure of Implants Loaded	25(2.2%)
Type of loading (%)	
Immediate	31(2.7%; n=2)
Delayed	1103(97.2%; n=15)
Years of follow up (months), mean ± SD (min-max)	28.5±14.45 (4-82; n=15)

TABLE 3 Demographic and clinical data of implants placed in grafted region as described in the literature

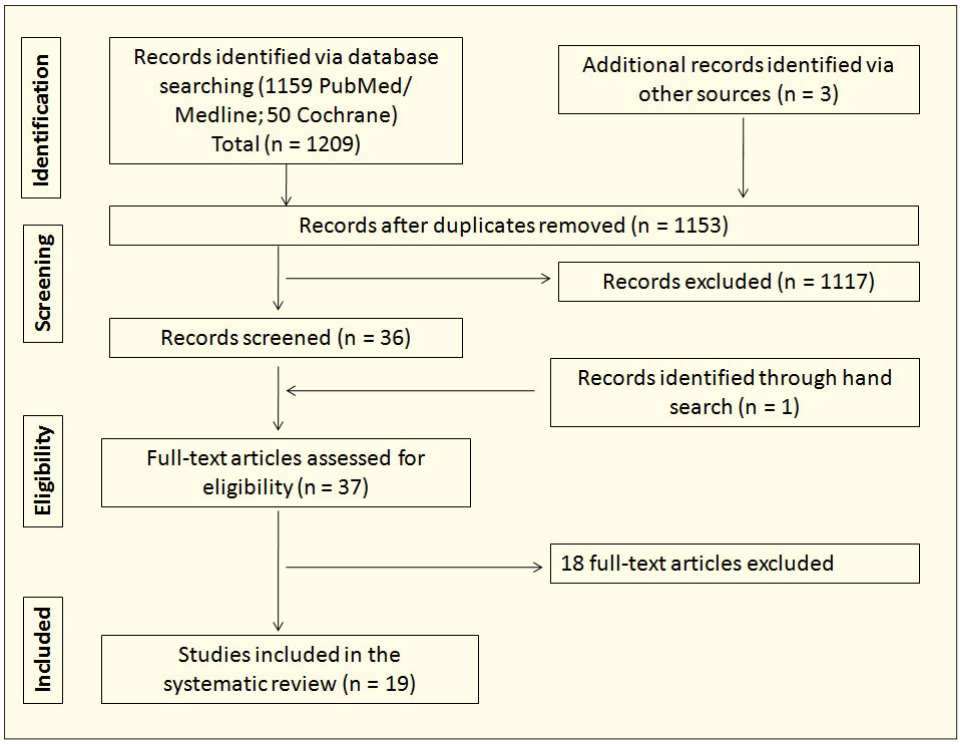

FIG 1 Screening of articles for their eligibility to be included in the systematic review

treatment effects. The statistical unit for 'graft failure' was the graft, and for 'implant failure was the implant. The heterogeneity of the studies was presented with I2 statistic; 25% as low heterogeneity, 50% as moderate and 75% as high heterogeneity.

Publication bias

A funnel plot was drawn to find publication bias. An asymmetry of the funnel plot indicated the presence of publication bias. The classic fail-safe N test was used to quantify the degree of publication bias. A rank correlation test and a regression test were performed for funnel plot asymmetry.

RESULTS

Literature search

Initially, the literature search resulted in 1212 papers. 1153 papers remained after excluding duplicate articles, out of which 1117 papers were further excluded following the screening the abstracts, resulting in 36 studies. Eighteen studies did not fulfil the inclusion criteria, hence were excluded (Fig 1). The hand search resulted in one additional paper, and finally, 19 articles were included in this review. The reviewers had a high level of agreement (k= 0.856).

Study description

An overview of the 19 included papers (9 prospective,(20,28) one retrospective,29five RCTs30-34 and four case-series35-38) is tabulated (Tab. 2). Eleven studies (21,23,25,28,31,34,36,37) were conducted at universities, six (22,26,27,29,35,38) at private clinics, one was a multicentre study (20) and one at a hospital (30). Minimum number of patients included were 5 in a study by Soltan et al.(35) and the maximum were (73) in a study by Keith et al.(20) Sixteen studies (20,22-25,27,32,34,38) included partially edentulous patients, one (21) included completely edentulous patients and two (26,33) included both. Eight studies (21,23,25,30,33,35,36,38) included augmentation procedure in maxilla, four (28,31,32) in mandible and seven (20,22,26,27,29,34,37)in both maxilla and mandible. Thirteen studies (20,22,24,27,28,30,33,35,36,38) reported a total of 438 defect sites, with maximum number of defect sites were 82 reported in a study by Keith et al,(20) and minimum was 5 in a case series by Soltan et al.(35) Smoking and/or other systemic diseases were reported in four studies, (20,26,29,34) absent in 12 studies (21-23,27,28,30,33,36,38) and not reported in three studies (24,25,35). Horizontal augmentation was done in eight studies,(21,30,33,38) vertical was done in one study,(32) and in 10 studies (20,22,29,31) both horizontal and vertical augmentation was done.

Demographic details of the included studies were tabulated (Tab. 3). A total of 136 males (30.8%) and 305 females (69.2%) were included from 18 studies. (20,30,32,38) Fifteen studies (20,21,23,28,30,33,35,36,38) reported procedures performed on 262 maxillary jaws (68.2%) and 122 mandibular jaws (31.8%). Total of 685 allogenic block graft were used in 18 studies (20-26,28-38), excluding Krasny et al.(27), for 368 horizontal augmentations in 12 studies (21,24,26,30,33,38) and 81 vertical augmentations in 6 studies (22,26,32). Allogenic block graft were fixed using screws in all 19 included studies (Tab..4). Membrane was used in 13 studies (20,22,26,28,29,31,32,36,38) all of which were resorbable membranes. Additional grafting materials were used in 14 studies. Bone graft survival was 100% in 7 studies,(20,22,28,35,37) 95% in one study (26) and 79.3% in one study (24). Sixteen (2.7%) blocks failed in four studies (20,23,24,32) and 70 (10.21%) block graft related complications were reported by 10 studies (20,21,23,25,27,32,34,36).

Implant related parameters, failures and survival rate are summarized in Table 5. Total of 1134 implants were placed in the augmented area in 18 studies (20,31,33,38), excluding Leong et al.(32) which did not report on number of implants placed. Implant loading protocol was immediate type in two studies (23,36) constituting 31 implants (2.7%) and delayed loading type in 15 studies (20,31,33,34,38) constituting 1103 implants (97.2%). Type of restoration was cement-retained in 4 studies, (23,25,29) screw-retained in one study (28) and 13 studies (20,22,26,27,30,31,33,38) did not report on the type of restoration. Mean follow-up of 15 studies (20,29,31,33,34,36,38) was 28.5±14.45 months. Crestal bone loss around implants was reported in six studies (23,2429,31,34,36). Seven studies, (20,22,25,28,33) reported failure of 25 implants (2.2%). Only one study38 reported implant success rate as 100% and 11 studies (21,26,27,29,31,34,38) reported 100% implant survival rate.

Histological findings

Histological findings were reported by eight studies (20,21,25,28,30,33,35,37). Formation and/or deposition of new bone on the allogeneic block graft, with no evidence of inflammatory reaction was seen during histopathologic evaluations. In studies by Keith et al.(20) and Pendarvis et al.(37) an amorphous eosinophilic material, consistent with residual platelet components, was found when PRP was applied during treatment.

Histomorphometric analysis of specimens were carried on in five studies (25,28,30,33,35). Nissan et al.(25) and Dias et al.(28) reported newly formed bone; residual cancellous block allograft; marrow and connective tissue of varying percentages. Da Costa et al.(30) reported mineralized vital bone 60.7±16.18% in test group (allograft and bone marrow aspirate) and 41.44±12.5% in control group (allograft alone), Deluiz et al.(33) found no differences in the amount of calcified tissue and percentage of newly formed bone. Soltan et al.(35) reported 89% of bone was vital and 11% of non-vital allograft.

Reference	Type and Number of augmentations	Blockgraft used/ Graft fixed/membrane used	Any other graft material or growth factors used	Bone augmentation at baseline (mm) / measurement method/ Post augmentation healing period	
Keith et al (2006)20	Horizontal & vertical n=not reported	n= 82 corticocancellous/fixation screws/resorbable	Particulate allograft and membrane (n=19 saturated in platelet rich plasma)	Not reported/radiograph /4-6 months	
Contar et al (2009)21	Horizontal n =34	n=34 human blockgraft of fresh frozen tibia/Mini screws/no	No	Not reported /radiograph/8-11 months	
Peleg et al (2010)22	Horizontal n=41; vertical n=16	n=57 allogeniccorticocancellous iliac/mini screws/freeze dried allogenicduramater	No	Not reported / orthopantomogram(OPG)/ 3-4 months	
Nissan et al (2011)23	Horizontal n= 42;vertical n=27	n=46cancellous freeze dried allografts/ bone screws/resorbable	Particulate bone, mineralized FDBA or bovine bone mineral	Not reported /computed tomography (CT)/ 3-4 months	
Nissan et al (2011)24	Horizontal n=23; vertical n=11	n=29 cancellous freeze dried allograft/ bone screws/resorbable	Particulate freeze dried bone allograft	Not reported /probe and CT/6 months	
Nissan et al (2012)25	Horizontal (n= not reported); vertical n=13	n=60 cancellous freeze dried allograft/ bone screws/resorbable	Particulate mineralized FDBA or bovine bone mineral	Not reported /CT/6 months	
Novell et al (2012)26	Horizontal n=15; vertical n=5	n=41 freeze dried allograft/titanium microscrews/resorbable	No	Not reported /CT and OPG/4-6 months	
Krasny et al (2015)27	Horizontal & vertical n= not reported	Allogenic frozen radiation-sterilised corticocancellous/screws/no	PRF	8.7 (7.3- 10)/not reported/3 months	
Dias et al (2016)28	Horizontal & vertical n= not reported	n=30corticocancellous fresh frozen allograft /titanium microscrews/ collagen	Particulate bovine mineral	Width=6.3±1.4;height=4.8±1.6 /cone beam computed tomography(CBCT) /6 months	
Schlee et al (2014)29	Horizontal & vertical n= not reported	n=48 autogenous graft; n=19 allograft/yes/collagen	Small bone chips	Not reported/radiograph/5-6 months	
da Costa et al (2011)30	Horizontal n=20	n=20 corticocancellous allograft/ titanium screws/no	Bone marrow aspirate	Test group (allograft and bone marrow aspirate)= 4.3; control group(allograft alone)= 4.8/ CT/ 6 months	
Amorfini et al (2014)31	Horizontal &verticaln= Not reported	n=16corticocancellous allograft / osteosynthesisscrew/ resorbable	A-Saline B- rhPDGF	Test group= 0.19cm3;Group A (saline)= 0.20cm3;Group B(rhPDGF)= 0.16cm3/CBCT/12 months	
Leong et al (2015)32	Vertical n=9	n=9 human mineralized allograft; n=10 allograft particulate/ titanium screws/ collagen	No	Test group =4; control group= 4/CBCT/6 months	

TABLE 4 Summary of studies on graft related parameters, outcomes and complications

	Final bone gain / re-entry width(mm)	Bone resorption (mm)/graft survival (%)	Failed blocks and reason of failure	Types of complications in relation to graft
	Not reported	Not reported/ 100	n=7 improper cont ouring,prosthesisim pingementand /or infection	n=7 soft tissue dehiscence
	Not reported	Not reported/ 100	0	n=1early exposition of block due to inadequate flap design during first stage surgery
	Horizontal=3.7; vertical = 2.3/not reported	Not reported/ 100	0	0
	Mean horizontal 5±0.5; vertical 2±0.5/not reported	Mean buccal bone resorption 0.5±0.5; no vertical bone resorption/ 95.6	n= 2 soft tissue breakdown, infection and loss of fixation	n=13-soft tissue breakdown and graft exposure;n=5 soft tissue dehiscence;n=2 loss of fixation
	Horizontal = 5.6; vertical =4.3/not reported	Buccal =0.5 at implant placement; 0.2mm at 2nd stage surgery/ 79.3	n=6 blocks failed	0
	Not reported	Not reported	0	n=16 soft tissue dehiscence
	Not reported	Not reported/ 95	0	n=1 fracture in upper third; n=3 exposures
	Maxilla:frontal section= 6.2;lateral section= 5.5; mandible:frontal section=5.1 ; lateral section= 6.1 /not reported	Not reported	n=1 failed due to damage of bone block fixation and was replaced	n=1 block exposure which was later treated
	Width=4.5±1.3; height =2.6±2 /not reported	45% of height and volume/100	0	0
	Not reported	1.60±1.03/Not reported	0	0
	Test group= 4.60±1.43; control group= 2.15±0.47/ not reported	Not reported	0	0
	Test group= 0.16cm3;Group A (saline)=0.17cm3;Group B(rhPDGF)=0.16cm3/not reported	Test group = 0cm3/3.3%;Group A=-0.03cm3/-11.8%; Group B= 0 cm3/ 0%/ Not reported	0	0
	Allograft block =1.78 ; auto particular =1; CBCT finding: Vertical:alloblock = 1.958; allograft particular= 0.958;horizontal: allograft=0.98; allograft particular – 1.667/ not reported	Not reported	n= 1 allograft block failure due to greater difficulty in achieving revascularization through a solid block form	n=2 allograft block incision opening & wound dehiscence

Reference	Type and Number of augmentations	Blockgraft used/ Graft fixed/membrane used	Any other graft material or growth factors used	Bone augmentation at baseline (mm) / measurement method/ Post augmentation healing period	
Deluiz et al (2017)33	Horizontal n=113	n=113fresh frozen allograft/titanium screw/no	No	Not reported/CBCT/ Group I=4 months;Group II=6 months	
Tresguerres et al (2019)34	Horizontal n=37	n=37 cancellous freeze dried allograft ; n=49 corticocancellous/ osteosynthesisscrew/no	PRGF as membrane	Not reported/digital caliper, radiograph and CT/4 months	
Soltan et al (2007)35	Horizontal n=7	n=7corticocancellous allograft/bone screw/no	Bone marrow aspirate	Not reported/CT/4-8 months	
Nissan et al (2008)36	Horizontal n=11	n=11cancellous allograft/bone screw/ no	No	Not reported/ probe and radiograph/4-6 months	
Pendarvis et al (2008)37	Horizontal n= 9	n=9 cancellous allograft /bone screw/ no	Particulate allograft & PRP	At crest =6.5; 1mm apical to crest =6.8; 3 mm apical to crest = 8.09; 5 mm apical to crest = 8.8 / caliper, probe and radiograph/6 months	
Wallace et al (2010)38	Horizontal n=16	n=16 freeze dried cancellous allograft/ bone screw and titanium tracks/ resorbable	Particulate FDBAPRP+rhPGDF-BB	3.9 /caliper, probe and CT/5 months	

TABLE 4 Summary of studies on graft related parameters, outcomes and complications

Quality assessment

All the 10 case-control and cohort studies included were of high quality (Tab. 6). All of the 5 included RCTs had low risk of bias (Tab. 7).

Meta-analysis

Included studies had shown no significant heterogeneity (I2 = 5.44%; P=0.390) in the forest plot for the event graft failure (Fig.2) and the Cochran's Q was 17.978 and was significant (P=0.006). Included studies also showed no significant heterogeneity (I2 = 13.97%; P=0.661) in the forest plot for the event implant failure (Fig.3) and the Cochran's Q was 14.098 and was also significant (P<0.001).

Publication bias

The assessment of publication bias is presented in Table 8. The funnel plot for the event graft failure (Fig 4) showed slight asymmetry, suggesting pres-

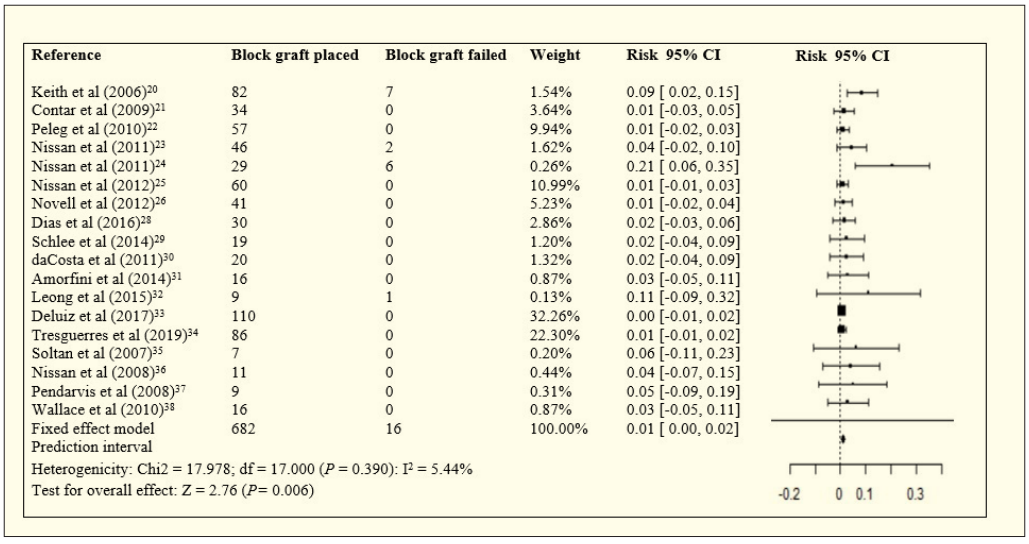

FIG 2
Forest plot for the event graft failure

	Final bone gain / re-entry width(mm)	Bone resorption (mm)/graft survival (%)	Failed blocks and reason of failure	Types of complications in relation to graft
	Histomorphometricfindings:Group I= 20.8% ±9.52;Group II= 27.2% ± 14.86/not reported	Group I=13.98%±5.59;Group II=31.52%±6.31/not reported	0	Group I n=6 infections; n=3 dehiscence;n=3 exposure. Group II n=2dehiscence;n=3 exposures
	Not reported	Cancellous =29.2%±2.6;corticocancellous= 19.3%±2.3/not reported	0	n=2 partial graft exposure which was sealed using PRGF
	Not reported	Not reported/ 100	0	0
	Not reported /5±0.5(4-6)	Not reported/ 100	0	n=1 minimal soft tissue dehiscence, which was resolved
	At crest =3; 1mm apical to crest =3.2; 3 mm apical to crest =3.1; 5 mm apical to crest = 3/ At crest = 5.7; 1mm apical to crest =6.3;3 mm apical to crest = 7.4; 5 mm apical to crest =8.25	Not reported/ 100	0	0
	4.6 (1.5-9.8) /8.39±1.95	Not reported	0	0

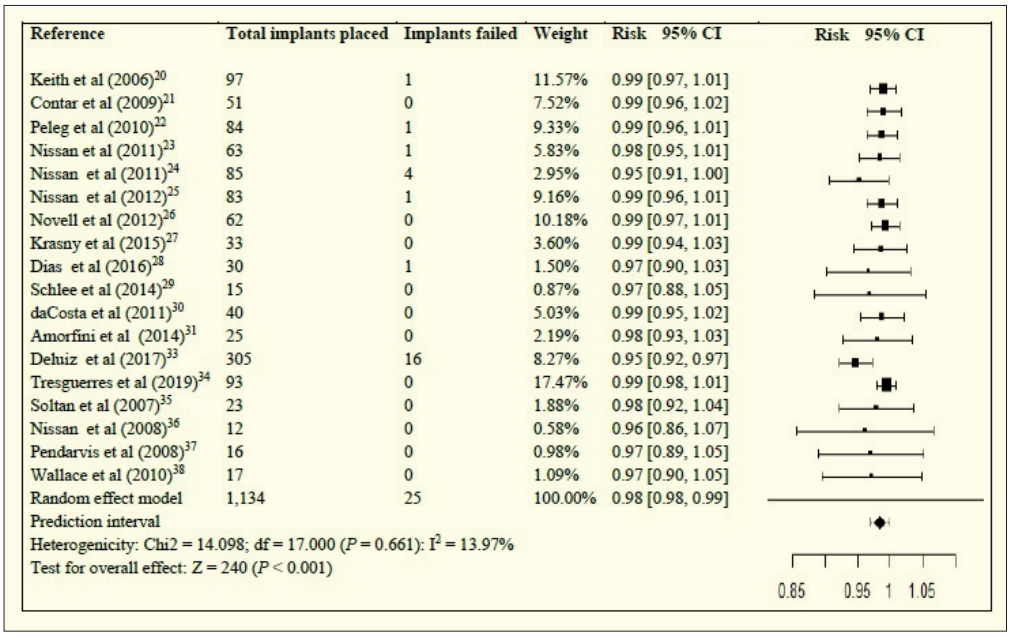

FIG 3
Forest plot for the event implant failure

ence of some amount of publication bias. The funnel plot for the event implant failure (Fig 5) also showed slight asymmetry suggesting presence of publication bias.

Discussion

Various techniques of ridge augmentation are available to increase the height (vertical) and width (horizontal) of the alveolar ridge giving effective and predictable results (39,40,41). Generally, survival rate of implants placed in augmented ridges is high (40,42) and reviews (8,40,43,45) had reported 95.5% for GBR, 90.4% for onlay grafts. The success rates following ridge augmentation with onlay block graft were 92% to 100%. Ten years long follow-up study reported success rates of 95% for simultaneous placement of autogenous bone grafts and implants (46). Other studies (11,47,48) showed no significant difference in the implant survival following ridge augmentation using autogenous bone or BSM.

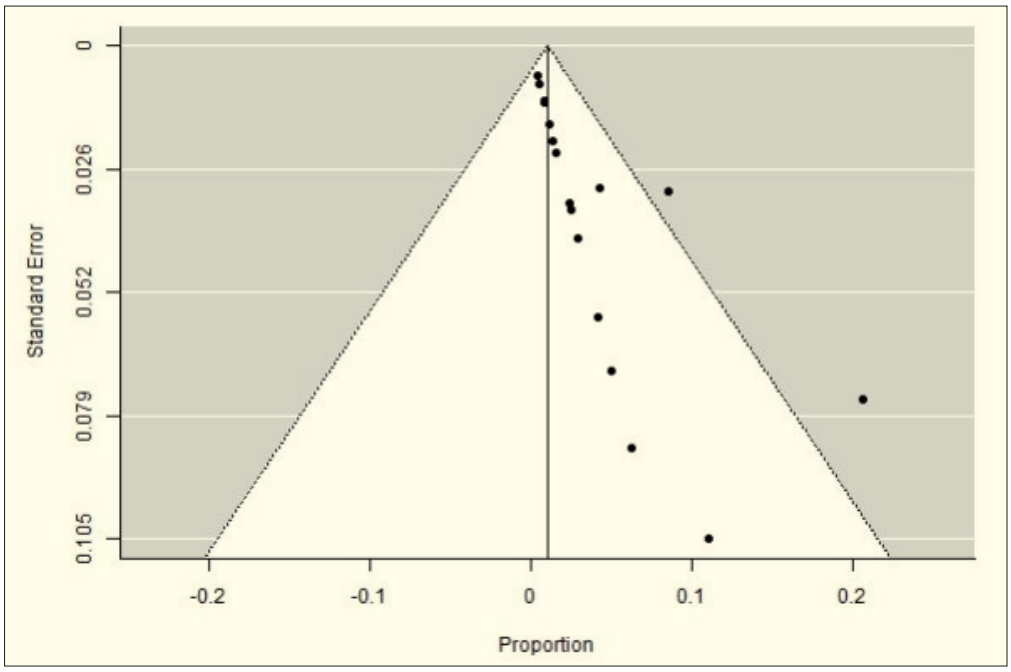

FIG 4
Funnel plot for the event graft failure

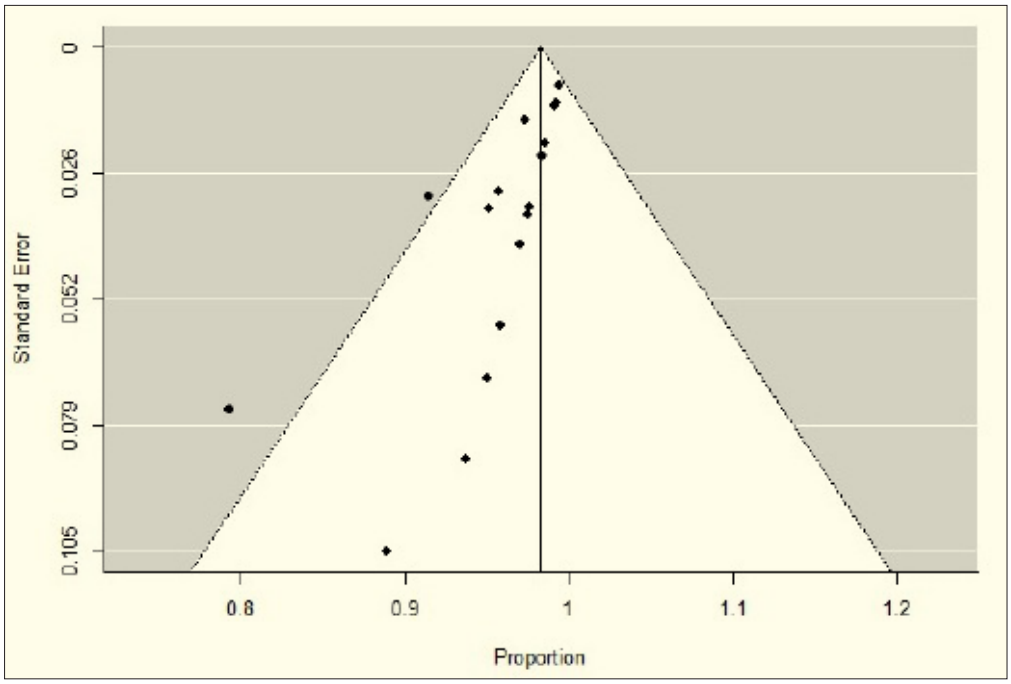

FIG 5
Funnel plot for the event implant failure after loading

The autogenous bone graft has provided implant success rate comparable to native bone with alveolar ridge width and height gain of 4 to 5 mm (49,52). The clinical applications of autogenous onlay graft are limited because of the restricted quantity of donor tissue and graft harvest related morbidity. Bone allografts [fresh-frozen bone or freeze-dried bone allograft (FDBA) and demineralized freeze-dried bone allograft (DFDBA)] involve the harvesting of bone from a human cadaver and also contain osteoinductive growth factors. Many studies have demonstrated their effectiveness in promoting new bone formation across a wide array of defect types (53,55) and it is also used as adjunctive grafting procedures in implant dentistry.

Biologic background of allograft

Allografts, as they are obtained from human cadavers so, variability in their content does exist. Sterilization procedures are done to maintain certain regenerative proteins and growth factors. Reports have shown that certain commercially available allografts are less osteoinductive due to patient variability and sterilization protocols (56,58) In majority of the augmentation procedures FDBA is routinely used, as DFDBA fails due

Reference	Number of implants placed	Type of implant loading / restoration	Implant follow-up (months)/ implants failed	Crestal bone loss around implants	Implant survival rate / success rate(%)
Keith et al (2006)20	97	Delayed / Not reported	25-36 /1	Not reported	99/ Not reported
Contar et al (2009)21	51	Delayed / Not reported	24-35/0	Not reported	100/ Not reported
Peleg et al (2010)22	84	Delayed/ Not reported	26 /1	Not reported	98.8/ Not reported
Nissan et al (2011)23	63	n=19 immediate n=44 delayed/ Cement retained	34/1	No crestal bone loss around implants beyond the 1st implant thread	98/ Not reported
Nissan et al (2011)24	85	Delayed / Cement retained	37 /4	0.5±0.2mm	95.2/ Not reported
Nissan et al (2012)25	83	Delayed / Cement retained	14-82 (48±22)/1	Not reported	98.8/ Not reported
Novell et al (2012)26	62	Delayed/ Not reported	60/0	Not reported	100/ Not reported
Krasny et al (2015)27	33	Delayed / Not reported	28-50 /0	Not reported	100/ Not reported
Dias et al (2016)28	30	Delayed / Screw retained	15.3-28.7 /1	Not reported	96.6/ Not reported
Schlee et al (2014)29	15	Delayed/ Cement-retained	11-53 /0	Around single implants = 1.91±3.3mm Around 2-3 adjacent implants= 1.45±1.15mm Around 4 or more implants= 1.05±1.38mm	100/ Not reported
da Costa et al (2011)30	40	Delayed / Not reported	Not reported/0	Not reported	100/ Not reported
Amorfini et al (2014)31	25	Delayed / Not reported	12 /0	A=0.78±0.52mm B=0.45±0.47mm	100/ Not reported
Leong et al (2015)32	Not reported	Delayed / Not reported	Not reported	Not reported	Not reported
Deluiz et al (2017)33	305	Delayed/ Not reported	12 /16	Not reported	94.7/ Not reported
Tresguerres et al (2019)34	93	Delayed/ Not reported	24 /0	Corticocancellous block graft group= 0.5±0.8 mm;Cancellous block graft group= 0.7±1.0 mm	100/ Not reported
Soltan et al (2007)35	23	Not reported	Not reported/0	Not reported	100/ Not reported
Nissan et al (2008)36	12	Immediate / Not reported	18 /0	Radiographs showed no bone loss beyond the 1st implant thread	100/ Not reported
Pendarvis et al (2008)37	16	Not reported	Not reported/0	Not reported	100/ Not reported
Wallace et al (2010)38	17	Delayed/ Not reported	4 /0	Not reported	100/ 100

TABLE 5 Summary of studies on implant related parameters, failures and survival rate

to quick resorption and radiolucent nature so not observed better on the radiograph. Allografts are free of the limitations and complications that are commonly associated with autogenous block graft and can undergo incorporation with bone formation and remodeling (20,35,37).

Corticocancellous versus cancellous block allograft

Allogenic block grafts can be cortical, cancellous, or a combination of both. Use of cancellous bone has shown good revascularization with easier penetration of blood vessels into the graft but at the same time it lacks resistance to mechanical stress. Cortical bone can withstand mechanical stress attributing to its solid structure, but has disadvantages like difficulty in revascularization, integration, and becoming a viable bone. Vascular tissue has to invade Haversian and Volkmann's canals, limiting the blood vessels penetration toward these pre-existent pathways, and this occurs following the enlargement of these canals by osteoclasts. Finally, osteoblasts are transported in these enlarged canal spaces where they form new bone (59,60). As the cancellous graft lacks the protective layer of cortical bone, so it leads to increased rate of resorption (22). When a cortico-cancellous graft

Reference	Selection				Comparability of cohorts		Outcome			Total
	Representativeness of the exposed cohort	Selection of external control	Ascertainment of exposure	Outcome of interest not present at start	Main factor	Additional factor	Assessment of outcome	Follow up long enough*	Adequacy of follow up	(9/9)
Keith et al (2006)20	*	0	*	*	*	*	*	0	*	7/9
Contar et al (2009)21	*	0	*	*	*	0	*	0	*	6/9
Peleg et al (2010)22	*	0	*	*	*	0	*	0	*	6/9
Nissan et al (2011)23	*	0	*	*	*	*	*	0	*	7/9
Nissan et al (2011)24	*	0	*	*	*	0	*	0	*	6/9
Nissan et al (2012)25	*	0	*	*	*	*	*	*	*	8/9
Novell et al (2012)26	*	0	*	*	*	*	*	*	*	8/9
Krasny et al (2015)27	*	0	*	*	*	0	*	0	*	6/9
Dias et al (2016)28	*	0	*	*	*	0	*	0	*	6/9
Schlee et al (2014)29	*	*	*	*	*	0	*	0	*	7/9

TABLE 6 Quality assessment of studies using the Newcastle-Ottawa scale (NOS)

Reference	Random sequence generation	Allocation concealment	Incomplete outcome data addressed	Blinding	Estimated potential risk of bias
da Costa et al (2011)30	Yes	Yes	Yes	Yes	Low
Amorfini et al (2014)31	Yes	Yes	Yes	Yes	Low
Leong et al (2015)32	Yes	Yes	Yes	Yes	Low
Deluiz et al (2017)33	Yes	Yes	Yes	Yes	Low
Tresguerres et al (2019)34	Yes	Yes	Yes	Yes	Low

TABLE 7 Cochrane collaboration's tool for assessing risk of bias of the included randomised trials

Groups	Fail-Safe N Analysis (File Drawer Analysis)		Rank Correlation Test for Funnel Plot Asymmetry		Regression Test for Funnel Plot Asymmetry	
	Fail-safe N	P	Kendall's Tau	P	Z	P
Graft survival	103.000	< .001	0.763	< .001	3.315	< .001
Implant survival	391456.000	< .001	-0.634	< .001	-1.624	0.104

TABLE 8 Assessment of publication bias

is used, it combines properties of both. The cancellous layer allows for more close adaptation with effective osteoconduction and vascular infiltration. The cortical bone provides sufficient resistance and prevents resorption in early stages of healing (34). Present review supports this concept with most predictable results showed by cortico-cancellous block allografts.

Role of screws for holding block allografts

The close adaptation of the graft to the host bone surface is important to decrease the marrow spacing. It is achieved with the use of lag screws by compression of the cancellous part of the allogeneic block and thus decreasing the space at the graft bone interface (22). Cancellous bone has dead spaces created due to the removal of organic components during allogeneic graft preparation. The compression created due to screws, decreases the dead space within the graft and increases the density of the graft. This phenomenon favours the migration of osteoblasts and promotes revascularization

and helps in the maintenance of graft stability (61). It also prevents the fibrous in growth between the allograft and the host (62).

Allogenic block graft failure

In the present systematic review, Keith et al.(20) reported 7 cortico-cancellous graft failures (2 anterior maxilla, 5 posterior mandible) due to improper contouring, prosthesis impingement and/or infection. Nissan et al.(23,24) reported cancellous freeze dried allograft failures, in one study (23) two failures seen in anterior maxilla due to infection, soft tissue breakdown and loss of fixation. In another study (24) reported 6 failures in posterior mandible, with no reasons mentioned. Leong et al.(32) reported one block failure in posterior mandible because of increased difficulty in achieving revascularization through a solid block form. In the present review, block graft failures were more in posterior mandible (63%) compared to maxilla (36.8%) which can be attributed to the greater difficulty in achieving revascularization in mandible due to thick cortical bone as compared to more cancellous bone in maxilla (22). Based on the type of block allograft, no differences were seen in the graft failure between cortico-cancellous and cancellous freeze dried block allografts.

Allogenic block graft related complications

Among graft related complications, soft tissue dehiscence (20,23,25,32,33,36) and graft exposure (21,23,26,27,33,34) were more common in the included studies, as with autogenous onlay grafts, resulting in either partial or complete loss of graft, and this was mostly seen in mandibular ridge augmentation (13,52). Though use of block allograft involves high risks, but when graft exposure was controlled, there was significantly higher vertical bone gain with the block allograft compared to the particulate bone allograft (32).

Allogenic block graft resorption

Resorption of block allograft is of more significance among all the disadvantages of horizontal or vertical bone grafting procedures (63,64). In the present systematic review, studies where resorbable membrane were used following placement of block allograft had reported bone resorption (23,24,29,28,31). Studies (33,34) in which block allograft were placed without use of membrane also showed bone resorption. This systematic review has found that there is limited evidence about the potential of barrier membranes to modify or reduce the resorption pattern of allogenic bone grafts.

Efficient restructuring is very important for the exact fit of graft and recipient site and is obtained by preparing the surface of the graft and recipient site. Atrophy during restructuring is reduced in the combination of the two layers of the graft. The method of preparation of allogenic bone graft in the tissue bank is one of the factors which control the resorption during restructuring. Radiation-sterilization weakens the collagen structure needed for scaffold for growth and differentiation factors during restructuring(65).

Does modifications of block allografts enhances bone regeneration?

Da Costa et al.(30) used allogeneic block graft in freeze-dried and fresh-frozen forms, and found that fresh-frozen forms were better with respect to bone regeneration. They found significant increase in alveolar thickness gain when the fresh-frozen allogenous bone block was modified with the autologous bone marrow aspirate. The stromal stem cells in the marrow might have differentiated into osteoblasts and enhances the osteogenic potential.66 In the study by Amorfini et al.(31) the infusion of rhPDGF-BB in the graft stabilized bone regeneration and limited the resorption after 1 year almost to the level of baseline. This may be due to stimulation of angiogenesis, which is both chemotactic and mitogenic for osteoblasts and gingival fibroblasts (67).

Higher incidence of complications such as dehiscence (approximately 30%), was seen in block allograft related procedures due to an incomplete vascularization of the graft in its outer part (68). Tresguerres et al.(34) in their study used autogenous membrane PRGF to cover the onlay allogenic block grafts following augmentation of atrophic edentulous ridges. They found that it reduced the risk of soft tissue dehiscence by promoting the soft tissue healing. Allografts obtained from ilium are often resorbed quickly when placed in the maxilla or mandible, due to various factors including hypoxic environment, change in vascular supply and local growth factors which affect the differentiation of stem cells to repair the defective sites (69). Soltan et al.(35) in their study found that the resorption tends to slow down, or balances for, the loss of bone volume when marrow aspirated from the iliac crest along with a mineralized matrix is used. This positive result may be due to the plasticity of the mesenchymal stem cells obtained from iliac crest, which differentiate into any tissue type regardless of their origin (70).

Study by Pendarvis et al.(37) found no significant difference in the hard tissue measurements with PRP treatment compared to patients without PRP treatment. Other research had found similar findings as PRP has limited value with allografts and the benefits would not be observable after a 6-month healing period (71-73). The goal of the augmentation for each site was to achieve a minimum gain in width of 7 mm for ideal esthetics and long-term stability of the tissue. In the study by Pendarvis et al.(37) in their study suggest an average bone gains of 3.0 to 3.2 mm, but an individual gains up to 7 mm were observed. Wallace et al.(38) used freeze dried cancellous block allograft along with PRP+rh-PGDF-BB and found positive effect in bone and soft tissue healing. This combination seems to beneficial in open-

ing of the flap or soft tissue dehiscence formation after surgical closure (38). In the present review, eight studies (21,30,33,34,35,36,37,38) did horizontal, one (32) vertical and ten (20,22,23,24,25,26,27,28,29,31) both horizontal and vertical augmentations. Results showed that the use of modified block allografts had similar outcomes with both horizontal and vertical augmentation.

Alveolar ridge augmentation with block allograft and dental implant

The bone density needed to obtain primary implant stability is one of the important criteria for success of implant (43). Evidence from systematic reviews conclude that, survival rate for implants placed in alveolar ridges that are either augmented with guided tissue regeneration or block graft are comparable to those in non-augmented bone; however, most reviews have seen considerable variability in success rates and heterogeneity in study designs (1,6,74). All the studies included in this review used bone augmentation prior to implant placement. Instability of graft particles may occur due to mucosal pressure or mechanical load and particulate graft may not have the same potential for staged ridge augmentation compared to a block graft (45,47).

Crestal bone loss around implants was reported by six (23,24,29,31,34,36) studies. As previously reported, marginal bone loss decreases significantly as the buccal bone thickness approaches 1.8 to 2 mm (31). Hence lateral augmentation should aim for at least 2mm of bone buccal to the implant to reduce marginal bone loss later. The use of particulate bone and barrier membranes allowed better ossification, thereby reducing marginal bone loss (24).

In this systematic review, four studies (24,26,31,36) used standard-diameter (3.3-5 mm) and standard-length (10-15 mm) implants while augmentation with bone allograft and found survival rates of 95.2%-100%. A favourable crown-to-implant ratio (1:1) can be achieved by using standard-length implants which helps in preserving marginal bone (24).

Most of the studies included in this review followed delayed loading protocol, with only two studies (23,36) following immediate loading protocol with no difference in terms of implant related complications or failure. The studies examined in this review provide evidence that successful alveolar ridge augmentation using allogeneic (cortico-cancellous or cancellous) block grafts (98% to 100%) can support high (95% to 100%) short-term (less than 5 years) implant survival rates.

The limitations of this review are diversity of treatment approaches, fewer studies with control groups, different healing time post augmentation, and short follow-up periods following implant placement. Further research with standardized criteria for defining implant success or failure for both simultaneous and staged protocols with longer follow-ups periods of randomized controlled studies with the assessment of parameters like implant insertion torque, initial stability, esthetic parameters and hard and soft peri-implant tissue stability following ridge augmentation with allogenic block graft for implant placement are needed so as to acquire meticulous evidence-based results.

Allogenic block graft for ridge augmentation has shown similar results to autogenous block graft with respect to both graft and implants success and provides an alternative to overcome the drawbacks or disadvantages from the use of autograft. Use of both cortico-cancellous and cancellous block allograft achieved desirable ridge width and height but modified block allografts does not seems to have any added advantage over unmodified block grafts in terms of implant success rate. There was lack of data exclusively on vertical augmentation when compared to horizontal augmentation and the available data shows no differences in horizontal and vertical augmentation with respect to graft and implant related outcomes. More block allograft failures were seen in mandibular posterior region. Implants survival rate was found to be more with standard length and diameter implants placed in the augmented sites.

Abbreviations:

GBR – Guided bone regeneration
PRISMA - Preferred reporting items for systematic reviews and meta-analyses
BSM - Bone substitute materials
PICO - Population, intervention, comparison, outcome
RCT - Randomised controlled clinical trials
CCT - Controlled clinical trials
NOS - Newcastle-Ottawa scale
RE - Random-effects
FE – Fixed-effects
FDBA - Fresh-frozen bone or freeze-dried bone allograft
DFDBA - Demineralized freeze-dried bone allograft
BMP - Bone morphogenetic proteins
rhPGDF - Recombinant human platelet-derieved growth factor

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