Review Article

Sandwich osteotomy with interpositional grafts for vertical augmentation of the mandible: A meta-analysis

ABSTRACT

Sandwich osteotomy is a technique for vertical augmentation based on the principle of a graft being placed between two pedicled native bones. The inherent vascularization helps in graft consolidation. The aim is to review the bone height gained, implant survival and pitfalls with sandwich osteotomy. The PICO model was used to identify the suitable studies for the review. Oxford level of evidence, Newcastle Ottawa Scale and Cochrane's tool for Systematic Reviews of Interventions was applied for identifying study quality. Meta-analysis was performed with the help of RevMan. Funnel plot was used to evaluate publication bias and bias during article selection. Difference in means was used as principal summary measure. Fixed effects model with inverse variance statistics was used. I2test statistics was applied to identify study heterogeneity. Forest plots were produced for the outcome variables with 95% confidence interval (CI) and overall treatment effects and subgroup effects at a significance level of 0.05. The overall implant survival rate ranged from 90%-100% and prosthetic survival rate from 87%-95%. An overall 6-10mm of bone can be gained in the anterior mandible and 4-8mm in the posterior mandible. A total of 1030 implants were placed of which 988 implants survived after the mean follow up periods (odds ratio: 0.77, 95% CI: 0.49-1.21). Implant survival is independent of the graft being used. Vertical augmentation in the posterior mandible is limited compared to anterior owing to the presence of inferior alveolar nerve and the keratinized tissue deficiency.

Keywords: Augmentation, dental implants, jaws, mandible, osteotomy, sandwich

INTRODUCTION

Background

Following tooth loss there is a progressive anatomical change in the jaws. Resorption initially occurs of the alveolar bone and then progresses to involve the basal bone.[1,2] In the mandible, the most frequent consequence of bone resorption is an inadequate bone height above the inferior alveolar nerve complicating implant placement.[3]

Schettler in 1976 is credited to the development of this technique for augmenting bone in the anterior mandible. Yeung in 2005 used this technique for posterior mandibular augmentation.[4,5]

A number of techniques are available for vertical augmentation of the mandible for implant based rehabilitation; guided bone regeneration, interpositional grafting, block bone, and distraction osteogenesis.[6]

The concept of sandwich grafting is that; a bone graft sandwiched between two pedicled bones with an internal

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cancellous marrow will undergo raid healing. The main advantage being the preservation of the attached gingiva.[7] Following a healing time of 3-4 months the implants can be placed.[6] Sandwich osteotomy is particularly suitable for medium 6-9 mm of vertical augmentation in the mandible.[6] In this after a vestibular incision and limited perisoteal dissection, an osteotomy is carried to raise a segment of bone cranially and an interpositional graft is inserted and stabilization is done with various fixation techniques.[8] Interpositional grafts have a vertical threshold of 4-8 mm. The disadvantages being limitation of vertical movement due to stretching of the lingual tissues, segment sequestrum, and technical difficulty.[9]

OBJECTIVES

1. To ascertain the implant survival rate among patients augmented with sandwich osteotomy of the residual alveolar ridge of mandible.
2. To appraise the bone height, bone gain achieved with this procedure and determine on the resorption of bone.
3. Specifically address the limitations and complications of the specific procedure.

METHODS

Protocol and registration

The current review is in accordance with the of PRISMA guidelines.[10] The PROSPERO registration ID of the study: CRD42021248337.

Search strategy

The PICO criteria have been used to assess the eligibility of the individual studies[11] [Table 1].

Table 1: Search strategy and study design in accordance with PICO model

Search strategy	Study design
Focused question	What is the implant survival rate amongst patients augmented with sandwich osteotomy of the residual alveolar ridge of mandible? What is the bone height achieved? What are the limitations and complications of the specific procedure?
Population:	Patients requiring vertical augmentation of the residual alveolar ridge for implant based rehabilitation.
Intervention	Sandwich osteotomy of the alveolus for implant rehabilitation. Interpositional bone grafting for vertical augmentation. Comparable and non-comparable interventions for different types of interposition grafts for vertical augmentation
Comparison	Comparable and non-comparable interventions for different types of vertical augmentation techniques (Onlay bone grafting) in mandible
Outcome	Implant survival rate, bone resorption, survival of superstructures, marginal bone resorption, complications
Study design	Clinical trials, prospective, retrospective studies and case series with ≥10 cases.
Language filters	English only
Search dates	Till March 2021
Databases	PubMed, clincaltrials.gov, ctri.nic.in, cochranelibrary.org
Journals	Oral surgery, dental, maxillofacial surgery, implant dentistry, dentistry.
Inclusion criteria	Augmentation of alveolus with sandwich osteotomy for implant based rehabilitation. Adequate data on follow up and implant success rates. Data on at least any one of the following; marginal bone loss, bone height achieved, complications and survival of superstructures.
Exclusion criteria	Case reports and case series with <10 cases. Animal and cadaveric studies. Inadequate data on outcome. Review articles. Technical note.

Inclusion criteria

1. Studies focusing on vertical augmentation with the mandible with interpositional bone grafts/sandwich osteotomy.
2. Randomized clinical trials, non-randomized clinical trials, prospective and retrospective studies, comparative and non-comparative studies.
3. Studies on humans.
4. Studies reporting at least one of the following primary outcomes; implant and prosthetic survival rates.

Exclusion criteria

1. Single case reports
2. Animal studies
3. Cadaver studies
4. Review articles
5. Letters
6. Commentary
7. Studies comparing sandwich osteotomy with other augmentation procedures.

Two authors (RNB and BB) screened all identifiable titles and abstracts independently. In addition, the reference lists of the subsequently selected abstracts and the bibliographies of the systematic reviews, human randomized and non-randomized controlled trials and; prospective and retrospective cohort studies were searched manually. For studies appearing to meet the inclusion criteria, or for which insufficient data in the title and abstract was available, the full text was obtained. Disagreements were solved through discussion between the reviewers. The inter rater reliability was assessed using Cohen's Kappa; values ≥0 indicated no agreement, 0.01-0.20 as none to slight, 0.21-0.40 as

fair, 0.41-0.60 as moderate, 0.61-0.80 as substantial and 0.81-1.00 as perfect agreement.

Search terms

(sandwich[All Fields] AND ("osteotomy"[MeSH Terms] OR "osteotomy"[All Fields]) AND implant[All Fields]) OR (interpostional[All Fields] AND ("transplants"[MeSH Terms] OR "transplants"[All Fields] OR "graft"[All Fields]) AND implant[All Fields]) (vertical[All Fields] AND augmentation[All Fields] AND ("mandible"[MeSH Terms] OR "mandible"[All Fields])) OR (vertical[All Fields] AND augmentation[All Fields] AND implant[All Fields]) segmental[All Fields] AND ("osteotomy"[MeSH Terms] OR "osteotomy"[All Fields]) AND ("mandible"[MeSH Terms] OR "mandible"[All Fields])

Outcome assessment

The primary outcome assessed was implant and prosthetic survival rates. Bone height achieved, bone gain, marginal bone loss, and complications were the secondary outcomes assessed in our study.

Quality assessment and level of evidence

Quality assessment of the selected studies was executed by Newcastle-Ottawa scale (for prospective and retrospective studies) and Cochrane's tool for Systematic Reviews of Interventions (for randomized controlled clinical trials). Scale was applied for cohort studies to judge each included study on selection of studies, comparability of cohorts, and the ascertainment of either the exposure or outcome of interest. Stars were awarded such that the highest quality studies were awarded up to nine stars. The Oxford Level of Evidence was used to assess the strength of the studies.[12,13]

The Oxford 2011 Levels of Evidence

Level Category of evidence

I SR (with homogeneity) of RCT
Individual RCT

II SR (with homogeneity) of cohort studies
Individual cohort study (including low-quality RCT. For example <80% follow-up)
'Outcome' research; ecological studies

III SR (with homogeneity) of case-control studies
Individual case-control study

IV Case series and poor-quality cohort and case-control studies

V Expert opinion without explicit critical appraisal, or based on physiology, bench research or first principles

SR = systematic review, RCT = randomized controlled trials.

Statistical analysis

Meta-analysis was done with the help of statistical software RevMan (Review Manager [Computer program], version 5.3, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Estimated analysis effect was considered significant where *P* value was <0.05. Funnel plot was used to evaluate publication bias and bias during article selection. Difference in means was used as principal summary measure. Fixed effects model with inverse variance statistics was used. I^2 test statistics was applied to identify study heterogeneity ($I2$ <25% – no heterogeneity, $I2$ value 50–75% – serious heterogeneity). Forest plots were produced for the outcome variables with 95% confidence interval (CI) and overall treatment effects and subgroup effects at a significance level of 0.05.

RESULTS

Participants

The literature search yielded a total of 173 articles electronic database (n = 173) [Figure 1]. In addition to this hand search of references mentioned in articles was done. After removal of the duplicates (n = 100), initial screening of titles and abstracts was performed by two independent reviewers (RB and BB). Thirty five articles were selected for full-text reading, 13 studies were included for review and 11 studies were included for meta-analysis, 22 studies were excluded [Table 2]. Any disagreements between reviewers during study selection process were solved by discussion. Kappa statistics was used to assess the inter rater reliability among the reviewers. A coefficient value between 0.61 and 0.80 indicated substantial agreement. A Kappa Value of 0.9 indicated definitive agreement. Quality assessments of each study are reported in Tables 3 and 4.

Study characteristics

Individual study characteristics are shown in Table 5. Most of the studies did not include any classification system for residual alveolar ridge except Stellingsma, their study included Cawood and Howell class VI cases. The follow-up period ranged from 12 months to 12 years with 1 year follow-up being the most common. The grafts used for augmentation procedure were autologous Iliac crest, xenografts, intra-oral autografts, and nanocrystalline hydroxyapatite.

Data synthesis

Implant and prosthetic success rate

Meta-analysis was done of 11 included studies using fixed-effect model. A total of 1030 implants were placed in patients who underwent sandwich osteotomy and inter-positional bone augmentation procedure to augment the bone before implant placement. According to the results of included studies, 988 implants survived after the mean follow-up periods (odds ratio: 0.77, 95% CI: 0.49-1.21).

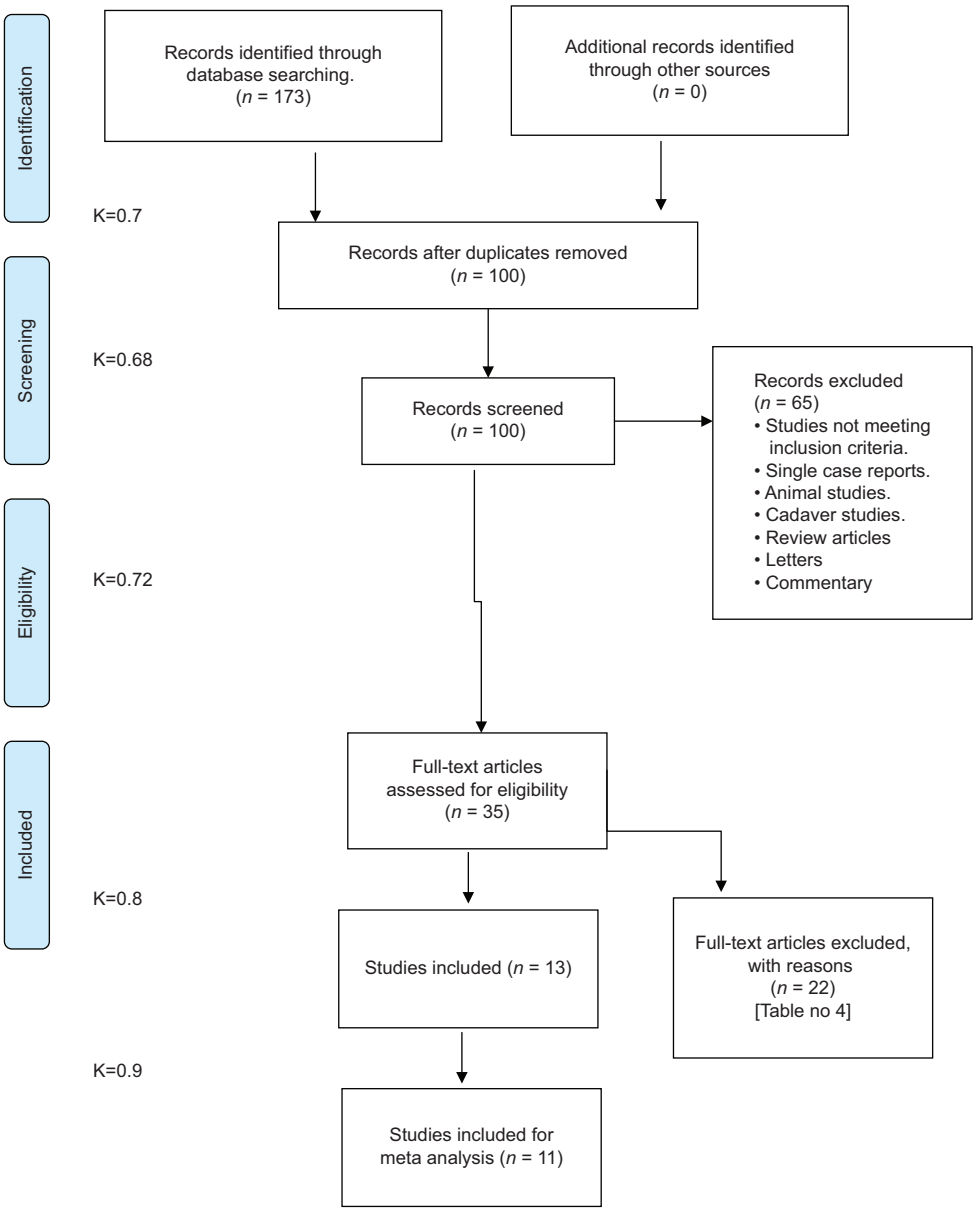

Figure 1: Study selection for review

Control was determined by considering the mean survival rate of dental implants after three year follow-up period as per previous study. [Figure 2][27] I^2 value was 0% in this analysis and Chi^2 value was less than degree of freedom signified low heterogeneity in between included studies [Figure 2 Forrest plot]. None of the included studies had significantly increased or decreased implant survival rate compared to mean implant survival rate as horizontal line of all the studies crossed the mid-vertical line of the plot [Figure 3]. Overall results showed that sandwich osteotomy and interpositional grafting procedure can be considered as a successful treatment procedure in cases with low available vertical bone height as there was insignificantly low implant implant survival rate compared to mean values (*P* value was 0.25). Test for funnel plot asymmetry (Figure 3 funnel plot) showing less chance of selection bias as both positive and negative studies were included in this review as studies are present on both sides of the vertical line.

Bone height achieved

Fellice 2009, Bormann 2010, Pelo 2010, Bormann 2011, Dottore 2012, Brandtner 2014, Barone 2017, Felice 2017, Marconcini 2018, and Geng 2019 reported bone height achieved or bone gain. Due to the heterogeneity in data reporting, a meta-anaylsis could not be performed. Table 6 reports the bone height achieved or bone gain as pointed out in individual studies.

Bone resorption

Bone resorption ranged from 0.5 mm to 2.3 mm. Pelo *et al.* showed that anterior to mental foramen the bone resorption

Table 2: Full text articles excluded with reasons

Study	Reference	Reason
Zétola *et al*. 2015	Zétola A, do Valle M, Littieri S, Baumgart D, Gapski R. Use of rhBMP-2/β-TCP for Interpositional Vertical Grafting Augmentation: 5.5-Year Follow-up Clinically and Histologically. Implant Dent. 2015;24 (3):349-53	Case rep ort
Mavriqi 2015 *et al*	Mavriqi L, Baca E, Demiraj A. Sandwich osteotomy of the atrophic posterior mandible prior to implant placement. Clin Case Rep. 2015;3 (7):610-4.	Case report
Castro *et al*. 2013	Pombo Castro M, Luaces Rey R, Arenaz Búa J, Santana-Mora U, López-Cedrún Cembranos JL. Prosthodontic rehabilitation in patient with ectodermal dysplasia combining preprosthetic techniques: a case report. Implant Dent. 2013;22 (5):460-4	Case report
Felice *et al*. 2010	Felice P, Piattelli A, Iezzi G, Degidi M, Marchetti C. Reconstruction of an atrophied posterior mandible with the inlay technique and inorganic bovine bone block: a case report. Int J Periodontics Restorative Dent. 2010 Dec; 30 (6):583-91	Case report
Santagata *et al*. 2017	Santagata M, Sgaramella N, Ferrieri I, Corvo G, Tartaro G, D'Amato S. Segmental sandwich osteotomy and tunnel technique for three-dimensional reconstruction of the jaw atrophy: a case report. Int J Implant Dent. 2017 Dec; 3 (1):14	Case report
Jensen *et al*. 2006	Jensen OT. Alveolar segmental "sandwich" osteotomies for posterior edentulous mandibular sites for dental implants. J Oral Maxillofac Surg. 2006;64 (3):471-5	Case report
Triaca *et al*. 2014	Triaca A, Brusco D, Asperio P, Guijarro-Martínez R. New perspectives in the treatment of severe mandibular atrophy: "double sandwich" osteotomy. Br J Oral Maxillofac Surg. 2014;52 (7):664-6	Technical note and review article.
Tulasne *et al*. 2012	Tulasne JF, Guiol J, Jeblaoui Y. Reconstruction pré-implantaire du secteur mandibulaire postérieur [Pre-implant posterior mandibular reconstruction]. Rev Stomatol Chir Maxillofac. 2012;113 (4):307-21	Article in French
Herford *et al*. 2013	Herford AS, Tandon R, Stevens TW, Stoffella E, Cicciu M. Immediate distraction osteogenesis: the sandwich technique in combination with rhBMP-2 for anterior maxillary and mandibular defects. J Craniofac Surg. 2013;24 (4):1383-7	Article not included as per eligibility criteria due to limited number of cases
Zhang *et al*. 1997	Zhang H, Zhou X, Wang X. [Mandibular ridge augmentation by sandwich osteotomy and BMP-HA implantation]. Zhonghua Kou Qiang Yi Xue Za Zhi. 1997;32 (1):37-9	Article in chinese
Ewers *et al*. 2004	Ewers R, Fock N, Millesi-Schobel G, Enislidis G. Pedicled sandwich plasty: a variation on alveolar distraction for vertical augmentation of the atrophic mandible. Br J Oral Maxillofac Surg. 2004 Oct; 42 (5):445-7	Case report
Felice *et al*. 2014	Felice P, Cannizzaro G, Barausse C, Pistilli R, Esposito M (2014) Short implants versus longer implants in vertically augmented posterior mandibles: a randomised controlled trial with 5-year after loading follow-up. Eur J Oral Implantol 7:359-369	Article was not included as per eligibility criteria.
Felice *et al*. 2018	Felice P, Barausse C, Pistilli V, Piattelli M, Ippolito DR, Esposito M (2018) Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long x 4 mm wide implants or by longer implants in augmented bone. 3-year post-loading results from a randomised controlled trial. Eur J Oral Implantol 11:175-187	Article was not included as per eligibility criteria
Esposito *et al*. 2014	Esposito M, Pistilli R, Barausse C, Felice P (2014) Three-year results from a randomised controlled trial comparing prostheses supported by 5-mm long implants or by longer implants in augmented bone in posterior atrophic edentulous jaws. Eur J Oral Implantol 7:383–395	Article was not included as per eligibility criteria
Novy *et al*. 2019	Novy LFS, Aguiar EG, de Arruda JAA, de Castro MAA, Moreira AN, Dos Santos EG, de Magalhães CS, Moreno A. Linear and volumetric gain after vertical bone -augmentation in the posterior mandible using an autologous cortical tenting method. Int J Oral Maxillofac Surg. 2019;48 (11):1485-1491.	Article was not included as per eligibility criteria
Simion *et al*. 2007	Simion M, Fontana F, Rasperini G, Maiorana C. Vertical ridge augmentation by expanded-polytetrafluoroethylene membrane and a combination of intraoral autogenous bone graft and deproteinized anorganic bovine bone (Bio Oss). Clin Oral Implants Res. 2007;18 (5):620-9	Article was not included as per eligibility criteria
Lee *et al*. 2008	Lee HJ, Choi BH, Jung JH, Zhu SJ, Lee SH, Huh JY, You TM, Li J. Vertical alveolar ridge augmentation using autogenous bone grafts and platelet-enriched fibrin glue with simultaneous implant placement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;105 (1):27-31	Animal study
Nguyen *et al*. 2019	Nguyen TTH, Eo MY, Kuk TS, Myoung H, Kim SM. Rehabilitation of atrophic jaw using iliac onlay bone graft combined with dental implants. Int J Implant Dent. 2019; 19;5 (1):11.	Article was not included as per eligibility criteria
Choi *et al*. 2004	Choi BH, Lee SH, Huh JY, Han SG. Use of the sandwich osteotomy plus an interpositional allograft for vertical augmentation of the alveolar ridge. J Craniomaxillofac Surg. 2004;32 (1):51-4	Article not included due to limited number of cases as per eligibility criteria
Bechara 2015	Bechara K, Dottore AM, Kawakami PY, Gehrke SA, Coelho PG, Piattelli A, Iezzi G, Shibli JA. A histological study of non-ceramic hydroxyapatite as a bone graft substitute material in the vertical bone augmentation of the posterior mandible using an interpositional inlay technique: A split mouth evaluation. Ann Anat. 2015;202:1-7	Histological study of bone quality from grafted sites. Study not relevant.
Domingues 2016	Domingues EP, Ribeiro RF, Horta MCR, Manzi FR, Côsso MG, Zenóbio EG. Vertical augmentation of the posterior atrophic mandible by interpositional grafts in a split-mouth design: a human tomography evaluation pilot study. Clin Oral Implants Res. 2017;28 (10):e193-e200	Inadequate participants and pilot study
Rachmiel 2018	Rachmiel A, Emodi O, Rachmiel D, Israel Y, Shilo D. Sandwich osteotomy for the reconstruction of deficient alveolar bone. Int J Oral Maxillofac Surg. 2018;47 (10):1350-1357	No separate data on mandibular sites being augmented.

Table 3: Quality assessment of the included studies (Newcastle Ottawa Scale)

Study	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis controlled for confounders	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts
Stellingsma 1998 (prospective)	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Bormann *et al*. 2010 (Prospective)	1 star	1 star	1 star	-	1 star	1 star	1 star	1 star
Pelo *et al*. 2010 (prospective)	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Bormann *et al*. 2011 (retrospective case series)	1 star	1 star	1 star	-	1 star	1 star	1 star	1 star
Dottore et al. 2012 (prospective)	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Brandtner *et al*. 2014 (case series)	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Barone *et al*. 2017 (retrospective)	1 star	1 star	1 star	-	1 star	1 star	1 star	1 star
Felice *et al*. 2017 (retrospective)	1 star	1 star	1 star	-	1 star	1 star	1 star	1 star
Noia 2017	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Marconcini *et al*. 2018 (prospective)	1 star	1 star	1 star	-	2 star	1 star	1 star	1 star
Geng *et al*. 2019 (retrospective)	1 star	1 star	1 star	-	1 star	1 star	1 star	1 star

Table 4: Quality assessment according to Cochrane tool

Study	Adequate sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective outcome reporting	Other risk of bias	Overall risk of bias
Felice *et al*. 2009 (Randomized controlled clinical trial)	Yes	Yes	Yes	Yes	Yes	Yes	Low
Felice *et al*. 2010 (Randomized controlled clinical trial)	Yes	Yes	Yes	Yes	Yes	Yes	Low

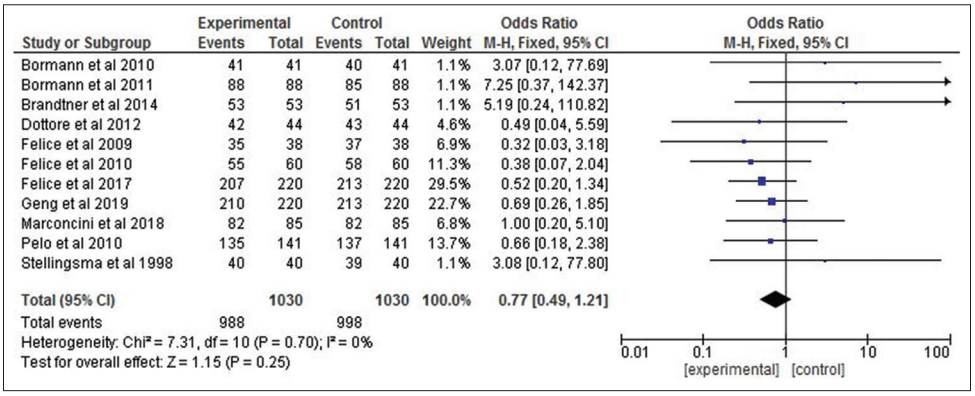

Figure 2: Meta-analysis

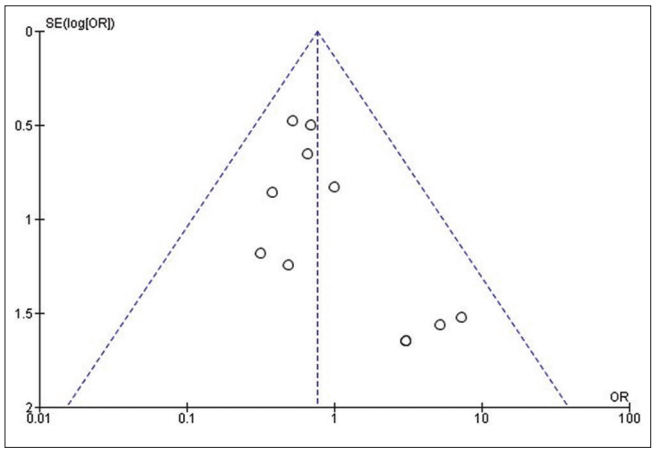

Figure 3: Funnel plot showing publication bias

was 41% and it increased to 46% 16 mm distal to mental foramen. Felice *et al*. in 2017 stated that equine bone had least amount of bone resorption followed by autologous bone and bovine bone. Felice 2009 stated that autologous bone had more resorption compared to bovine bone. Autologous bone was Iliac crest in both the studies. Both Marconcini *et al*. and Geng *et al*. showed that bone resorption is a dynamic process and with increased follow-up resorption also increased [Table 6].

Complications

The individual complications of each study are tabulated in Table 6. Transient neurosensory disturbances, graft failure, fractures, screw loosing, sequestrum formation, etc., were the most common complications.

Table 5: Study characteristics, demographics and follow-up

Study	No. of participants (no.of implants)	Age of participants	Pre-operative bone height	Site augmented	Grafts used.	Follow-up
Stellingsma 1998[14] (prospective)	10 (40)	Mean: 50	Cawood and Howell class VI. Mean: 11.7mm (8.7-14.3mm)	Mandible	Monocortical Iliac crest	24-30 months
Felice 2009[15] (RCT)	10 (38)	Mean: 54.9	5-7mm	Mandible	Iliac crest vs bovine anorganic bone	1 year
Felice 2010[16] (RCT)	60. 30 patients in augmentation group (61)	Mean: 55	7-8mm	Mandible	Block bovine bone	1 year
Bormann *et al*. 2010[17] (PCS)	13 (41)	Mean: 48, 61	Minimum: 4mm above mandibular canal.	Mandible	Autografts from intraoral site.	1 year
Pelo *et al*. 2010[18] (prospective)	19 (141)	Mean: 58.8	≥5 mm	Mandible	Iliac crest	3.8 years
Bormann *et al*. 2011[19] (retrospective case series)	27 (88)	Mean: 62.66, 57.61)	≥4 mm	Mandible	Block autograft and particulate grafts from intraoral site	17.5 months
Dottore *et al*. 2012[20] (prospective)	11 (44)	54.2	4-5 mm	Mandible	Autologous ramus vs nanocrystalline HA.	1 year
Brandtner *et al*.[21] 2014 (case series)	18 (53)	59	5-8 mm	Mandible	Autologous ramus graft, bovine bone	Mean: 31 months
Barone *et al*. 2017[22] (retrospective)	20 (80/46) 10 in the inlay group	NA	3-7 mm	Mandible	Xenografts	1 year
Felice *et al*. 20 17[23] (retrospective)	115 (266)	54.82	≥4 mm	Mandible	Autologous bone, xenografts.	4.2 years
Noia *et al*. 2017[24]	14 (40)	41 years	-	Mandibular anterior and posterior region	Autogenous bone (Mandibular ramus, menton), synthetic bone particles and collagen memebrane	-
Marconcini *et al*. 2018[25] (prospective)	23 (91)	49.7	3-7 mm	Mandible	Xenograft	3 years
Geng *et al*. 2019[26] (retrospective)	63 (220)	61	6.9±0.3 mm (posterior) 19.4±1.4mm	Mandible	Xenograft	58 months (upto 12 years)

DISCUSSION

Key results

The overall implant survival rate ranged from 92 to 100%. The overall prosthetic success rate was in the range of 87.20–96.80%. Of the total studies included for meta-analysis, out of 1030 implants being placed 988 implants survived after individual follow-up. There was a lack of heterogeneity in the studies included and as such sandwich osteotomy with interpositional grafting can be considered as a successful procedure. The bone resorption in our included studies ranged from 0.5 mm to 2.3 mm.

Limitations

1. Poor quality and evidence from the studies as most of them are case series and observational studies.
2. Very few comparative studies to draw out any definitive conclusion.
3. Meta-analysis could not be performed on graft resorption, bone height achieved, and bone height gain because of heterogeneity of data.

Interpretation

Schettler *et al.* introduced the concept of sandwich osteotomy for vertical augmentation of anterior mandible edentulous areas for retention of complete dentures.[28] The basis being the intact vascularization provided by intact lingual mucoperisoteum and two osteotomized segments above the mandibular nerve.[26] The drawbacks of other augmentation procedures led Yeung in 2005 to use this technique for vertical augmentation of posterior mandible.[5]

Felice *et al*. 2010[17] compared short implants versus vertical augmentation of the posterior mandible. They concluded that both treatment options are viable as long as the residual bone height is more than 7 mm. Two patients had augmentation failure because of fracture of the bovine block. The 2016 study by the same author[16] compared iliac crest graft with block bovine bone. The study gave comparable results with both the grafts. There was more residual bone in the bovine group because of slower resorption of bovine bone compared to autogenous bone. However, the difference did not lead to any significant clinical benefit. To maintain the stability

Table 6: Individual study outcomes

Study	Bone height achieved/ bone gain	Resorption	Implant success	Prosthetic success	Complications	Level of Evidence
Stellingsma 1998[14]	NM	0.5 mm-1.2 mm	100%	NR/NM	Mucosal dehiscence.	III
Fellice 2009[15]	Iliac: +31% Bovine: 27%	Iliac: 0.82 mm Bovine: 0.59 mm	Overall: 92% Iliac: 89% Bovine: 95%	Overall: 95%	Iliac: graft removed, 1 prosthesis could not be placed, 2 implants could not be placed, 2 dehiscences, 1 peri-implantitis Bovine: 1 implant mobility, 1 soft tissue dehiscence	II
Felice 2010[16]	NA	1.00±0.36mm	90%	90%	Augmentation failures: 2 Complications before implant placement: 4 (dehiscence, bone graft fracture) Transient paresthesia: 57%	II
Bormann *et al*. 2010[17]	Mean: 4.61 (2-7.8mm)	NM	100%	NA/NM	Transient neurosensory disturbance: 5 Mucositis: 1 Vestibular abscess: 1	IV
Pelo *et al*. 2010[18]	8 mm chin area 4.7 mm at 8 mm distal to mental foramina 3.9 mm at 16 mm distal to mental foramina. Bone height achieved: 16 mm	41% symphyseal area 43% at 8 mm distally from mental foramina 46% at 16 mm distally from mental foramina	91-96%	NM	Fractures: 3 Sequestrum: 3 Transient neurosensory disturbance: 1	IV
Bormann *et al*. 2011[19]	3.41±2.76 (0.3 to 12) mm	NM	100%	NM	Dehiscence: 3 Transient neurosensory disturbance: 6	IV
Dottore *et al*. 2012[20]	ramus: 11.5 mm HA: 12 mm	Ramus: 0.84 mm Ha : 0.71 mm	95.5%	NM	Abustment screw loosening in ramus group.	IV
Brandtner *et al*. 2014[21]	4.2±1.4 mm	2.3mm	100%	NM	Transient neurosensory disturbance: 1	IV
Barone *et al*. 2017[22]	6 mm	1.7mm	NM	NM	Wound dehiscence-1 Transient paresthesia of the mental nerve-8 Fracture-1	IV
Felice *et al*. 2017[23]	Autologous: 9.09 mm Bovine: 9.48 mm Equine : 9.75 mm	ABG: 1.34±0.50 mm Bovine : 1.37±0.62 mm (7 y) Equine: 0.61±0.27 mm	ABG : 94.4% Bovine: 91.1% Equine : 96%	ABG: 80% Bovine: 88.5% Equine: 93.1%	ABG: 7 temporary lip and buccal paresthesia, 2 dehiscensce, 1 block removal Bovine: 36 temporary lip and buccal paresthesia, 2 dehiscenses, 3 partial block removal Equine: 22 transient lip and buccal paresthesia, 5 dehiscense, block removal (1 total, 4 partial	III
Marconcini *et al*. 2018[25]	5.9 mm	B aseline -3 months: 0.18±0.29 mm Baseline-1 year: 0.63±0.37 mm Baseline: 2 year: 0.91±0.35 mm Baseline-3 years: 1.06±0.37 mm	96.6%	96.8%	Transient paresthesia of the mental nerve Dehiscence Mandible fracture	IV
Geng *et al*. 2019[26]	7.8±0.9 mm-overall. Partial edentulous group Anterior: 5.9±1.4 mm Posterior: 4.8±1.4 mm Full edentulous group: Anterior: 8.3±1.4 mm Posterior: 7.8±0.8 mm	0.22: 3 months 0.45: 6 months 0.74: 12 months 0.76: 36 months 0.95:60 months 0.97:144 months	96.7%-overall Partial edentulous: 97.6% Full edentulous: 95.1%		Fracture: 1 Wound healing disturbance: 18 Deficiency in keratinized tissue: 14 Transient paresthesia: 18	IV

of the cranial fragment a minimum of 5 mm bone above the mandibular canal is required to apply fixation and avoid graft collapse. Dottore *et al*.[20] compared intraoral ramus grafts and hydroxyapatite grafts for vertical augmentation. Their study also showed comparable results. Felice *et al*. 2017[23] compared autologenous iliac crest graft, bovine and equine graft and showed comparable results in terms of vertical bone height gain. There was no difference in implant and prosthetic failures amongst the groups. On long-term follow-up, there was no difference in peri-implant marginal bone loss among the groups.

Vertical bone height gain is more predictable in the anterior mandible region compared to posterior areas. Geng *et al*.[26] had a mean bone height gain of 5.9 mm compared to 4.8 mm in the posterior region. Pelo *et al*. also had better bone height gain in the anterior region. The mean bone gain was 8 mm in the symphysis, 5.6 mm (8 mm) distal to the mental foramen and 4.7 mm (16 mm) distal to the mental foramen. The survival rate of implants was also better in the symphysis region compared to molar regions.[18] The posterior areas of the mandible limit the stretching of the lingual mucosa in order to prevent devascularization and as such anterior areas become more accessible compared to posterior areas of the mandible leading to better vertical bone height gain. Further, a safety margin of 4-5 mm above the nerve is required and keratinized tissue deficiency which limits the bone gain to a range of 4-8 mm in posterior mandible compared to 6-10 mm in the anterior mandible.[18,26] In our review the included studies showed comparable results with autologous and bone substitutes considering implant survival. Grafts placed in between the two osteotomized fragments are better able to integrate owing to the vascularization of native bone and as such no significant difference in implant survival could be observed.[18]

A 2016 network meta analysis[29] compared autologous bone and bone substitutes regarding bone forming percentage before implant placement. There was no significant difference in new bone formed comparing autografts, xenografts, and allografts. Autografts had the highest percentage of new bone followed by synthetic grafts, xenografts, and allografts. However, the treatment ranking was based on moderate confidence owing to imprecision, limited data, and inconsistency. As stated by Dottore *et al.* in sandwich technique the placement of graft material in a three to five walled cancellous compartment leads to better vascularization and graft integration and hence the implant survival does not necessarily depend on graft type being used. The lack of significant difference in Radiofrequency analysis and peri-implant marginal bone loss also confirms the statement.[20] As stated by Geng *et al*. smoking is a dominant risk factor affecting implant survival and not the type of graft, age or the state of edentulism.

Commonly encountered complications with sandwich osteotomy are nerve injury, tissue dehiscence, and fracture. Keratinized tissue deficiency is one of the limiting factors in sandwich osteotomy. To avoid tissue dehiscence, 20.9% of patients in the study by Geng *et al*. received tissue transplantations. Dehiscences are common with sandwich technique and can often be related to surgical technique.[23]

The overall incidence of mandibular nerve paresthesia ranged from 20 to 55%. None of the included studies had any patients with permanent paresthesia. As stated by Stellingsma *et al.,* a safety margin of 5 mm avoids any sort of neurosensory damage. This transient paresthesia can last from few days to few weeks, the longest recorded six weeks.[23] This nerve injury can occur from nerve blocks, surgical technique, and flap elevation.[26]

CONCLUSION

Sandwich osteotomy is a successful procedure for vertical bone augmentation in the mandible. Overall a bone gain of 6-10 mm in the anterior region and 4-8 mm in the posterior region can be obtained with this procedure. The overall implant survival rate ranged from 90 to 100% and prosthetic survival rate from 87 to 95% with very low heterogeneity.

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Conflicts of interest

There are no conflicts of interest.

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