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a Systematic Review

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Prosthetic Rehabilitation of the Partially Edentulous Atrophic Posterior Mandible with Short Implants (≤ 8 mm) Compared with the Sandwich Osteotomy and Delayed Placement of Standard Length Implants (> 8 mm): a Systematic Review

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ABSTRACT

Objectives: Test the hypothesis of no difference in prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard lengths implants (> 8 mm).
Material and Methods: A MEDLINE (PubMed), Embase and Cochrane library search in combination with a hand-search was conducted by including studies published in English. No year of publication restriction was applied.
Results: Six randomized controlled trials characterized by low or moderate risk of bias fulfilled the inclusion criteria. There were no statistically significant differences ($P > 0.05$) in the survival rate of suprastructures and implants between the two treatment modalities after one year. Sandwich osteotomy and delayed implant placement demonstrated statistically significant higher long-term peri-implant marginal bone loss as well as biological and technical complications compared with short implants ($P < 0.0001$). Moreover, patients significantly favoured prosthetic rehabilitation with short implants ($P < 0.0001$).
Conclusions: Short implants and the sandwich osteotomy with delayed placement of standard length implants appear to result in predictable outcomes in terms of high survival rate of suprastructures and implants after prosthetic rehabilitation of the partially edentulous atrophic posterior mandible. However, further long-term randomized controlled trials assessing donor site morbidity, an economic perspective, professional and patient-related outcome measures with the two treatment modalities are needed before definite conclusions can be provided about the beneficial use of short implants for prosthetic rehabilitation of the partially edentulous atrophic posterior mandible compared with the sandwich osteotomy and delayed placement of standard length implants.

Keywords: dental implants; dental prosthesis; oral surgical procedures; randomized controlled trial; review.

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INTRODUCTION

Prosthetic rehabilitation of complete, partial or single edentulism with an implant-supported fixed prosthesis is a predictable treatment option with high long-term survival rates of suprastructures and implants [1-4]. However, placement of standard length implants in the partially edentulous atrophic posterior mandible is frequently compromised or impossible due to lack of sufficient vertical alveolar ridge height above the inferior alveolar nerve. Several bone augmentation techniques have been advocated to increase the vertical alveolar ridge height prior to predictable and optimal placement of standard length implants including alveolar distraction osteogenesis, onlay block grafting, guided bone regeneration and the sandwich osteotomy with an interpositional grafting material [5-8]. These bone augmentation techniques are technically demanding and associated with an increased risk of postoperative morbidity, prolonged patient treatment time, risk of neurosensory disturbances, resorption of the grafting material and imply a higher economic cost as well as more biological and technical complications [9-11]. Therefore, placement of short implants has been proposed as an alternative treatment modality for prosthetic rehabilitation of the partially edentulous atrophic posterior mandible to avoid complementary surgical procedures and diminish postsurgical morbidity [5,6,12-18].

Short implants have demonstrated high survival rate of suprastructures and implants after prosthetic rehabilitation of the partially edentulous atrophic posterior mandible, as documented in systematic reviews [5,6,12-15]. However, a newly published systematic review and meta-analysis concluded that placement of short implants with length less than 8 mm present greater risk of implant failures [12]. Moreover, a higher risk of implant failure has also been reported when the vertical alveolar ridge height is less than 10 mm [18]. Consequently, the optimal treatment for prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with implants remains inconsistent.

The sandwich osteotomy with an interpositional grafting material and delayed placement of standard length implants have revealed high survival rates of suprastructures and implants after prosthetic rehabilitation of the partially edentulous atrophic posterior mandible, as documented in systematic reviews [5-7]. Moreover, few biological and technical complications have been reported with the sandwich osteotomy and an interpositional grafting material [18]. Newly published systematic reviews and meta-analysis revealed a slightly higher implant loss and complication rate after placement of standard length implants in vertically augmented sites compared to the use of short implants in the posterior part of the maxilla and mandible [19,20]. From a clinical and patient perspective, it would be an advantage if the partially edentulous atrophic posterior mandible could be prosthetically rehabilitated with the use of short implants compared to the sandwich osteotomy with an interpositional grafting material and delayed implant placement. The implant treatment outcome following prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants has not yet been assessed specifically in a systematic review. Therefore, the objective of the present systematic review was to test the hypothesis of no difference in the prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard length implants (> 8 mm).

MATERIAL AND METHODS

Protocol and registration

The methods of the analysis and inclusion criteria were specified in advance and documented in a protocol. The review was registered in PROSPERO, an international prospective register of systematic reviews. The protocol can be accessed at: https://www.crd.york.ac.uk/prospero/. Registration number: CRD42018096183. The present systematic review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews [21].

Types of publications

The present systematic review included studies on humans. Letters, editorials, PhD theses, letters to the editor, case reports, abstracts, technical reports, conference proceedings, animal or *in vitro* studies and literature review papers were excluded.

Types of studies

The review included exclusively randomized controlled clinical trials assessing prosthetic rehabilitation of the atrophic posterior mandible

with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard length implants (> 8 mm).

Types of outcome measures

The primary outcome measures included:

- Survival of suprastructures. Loss of suprastructure was defined as a total loss because of a mechanical and/or biological complication.
- Survival of implants. Loss of implants was defined as mobility of previously clinically osseointegrated implants and removal of non-mobile implants due to progressive peri-implant marginal bone loss and infection.

In addition, the following secondary outcome measures were assessed:

- Primary implant stability.
- Radiographic peri-implant marginal bone loss (PIMBL).
- Professional and patient-reported outcome measures (PPROM).
- Biological and technical complications.

Information sources

The search strategy incorporated examinations of electronic databases, supplemented by a thorough hand-search page by page of relevant journals including "British Journal of Oral and Maxillofacial Surgery", "Clinical Implant Dentistry and Related Research", "Clinical Oral Implants Research", "European Journal of Oral Implantology", "Implant Dentistry", "International Journal of Oral and Maxillofacial Implants", "International Journal of Oral and Maxillofacial Surgery", "International Journal of Periodontics and Restorative Dentistry", "International Journal of Prosthodontics", "Journal of Clinical Periodontology", "Journal of Dental Research", "Journal of Oral Implantology", "Journal of Oral & Maxillofacial Research", "Journal of Periodontology", "Journal of Prosthetic Dentistry", "Journal of Craniofacial Surgery", "Journal of Cranio-Maxillo-Facial Surgery", "Journal of Oral and Maxillofacial Surgery", "Periodontology 2000", "Oral and Maxillofacial Surgery", "Oral Surgery Oral Medicine Oral Pathology Oral Radiology". The manual search also included the bibliographies of all articles selected for full-text screening as well as previously published reviews relevant for the present systematic review. The search was performed by both authors (TSJ and HBN). Any disagreements were resolved by consensus between the two observers.

Search

A MEDLINE (PubMed), Embase, and Cochrane Library search was conducted. Human studies published in English until the 9th of May, 2018 were included. The search strategy was performed in collaboration with a librarian and utilized a combination of Medical subject heading (MeSH) and free text terms. The search strategy is outlined in Appendix 1 - 3.

Selection of studies

The titles of the identified reports were initially screened. The abstract was assessed when the title indicated that the study was relevant. Full-text analysis was obtained for those with apparent relevance or when the abstract was unavailable. The references of the identified papers were cross-checked for unidentified articles. The study selection was performed by both reviewers (TSJ and HBN). Any disagreements were resolved by consensus between the two observers.

Study eligibility

The inclusion criteria were developed using the PICOS guidelines (Table 1).

Table 1. PICOS guidelines

Patient and population (P)	Healthy patients (> 18 years) with partially edentulous atrophic posterior mandible.
Intervention (I)	Prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants.
Comparator or control group (C)	Prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with the sandwich osteotomy and delayed placement of standard length implants.
Outcomes (O)	Survival of suprastructures, survival of implants, implant stability, peri-implant marginal bone level, professional and patient-reported outcome measures as well as biological and technical complications.
Study design (S)	Randomized controlled trials in humans.
Focused question	Are there any differences in the prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared to the sandwich osteotomy with an interpositional grafting material and delayed placement of standard length implants?

Inclusion criteria

Randomized controlled trials assessing the prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants by addressing the previously described outcome measures. The review exclusively focused on studies with an observation period of minimum one year after functional loading. In addition, at least 10 patients should be included in the study and the surgical technique, as well as the number of inserted implants must be clearly specified.

Exclusion criteria

The following exclusion criteria were applied: non-randomized controlled trials, retrospective studies, case series and cohort studies. Moreover, studies with implant placement in medically compromised patients or insufficient description of the length of the observation period, as well as studies involving the sandwich osteotomy without fixation of the mobilized cranial segment or no interpositional grafting material were excluded. Likewise, studies adding growth factors, bone morphogenetic proteins, fibrin glue or platelet-rich plasma to the interpositional grafting material were also excluded.

Data extraction

Data were extracted by one reviewer (TSJ) according to a data-collection form ensuring systematic recording of the outcome measures. In addition, relevant characteristics of the study were recorded. The corresponding author was contacted by e-mail in the absence of important information or uncertainties.

Data items

The following items were collected from the included articles and arranged in the following fields: study, year of publication, patient, vertical alveolar ridge height, implants, prosthetic solution, time before loading, length of observation period, survival of suprastructures, survival of implants, implant stability, PIMBL, PPROM, biological and technical complications.

Assessment of methodological quality

The quality assessment of the included studies was undertaken as part of the data extraction process. A methodological quality rating system was used and the classification of the risk of bias potential for each study was based on the following five criteria [22]:

- Random selection in the population (yes/no).
- Definition of inclusion and exclusion criteria (yes/no).
- Report of losses to follow-up (yes/no).
- Validated measurements (yes/no).
- Statistical analysis (yes/no).

The studies were grouped according to:

- Low risk of bias (plausible bias unlikely to seriously alter the results) if all above-described quality criteria were met.
- Moderate risk of bias (plausible bias that weakens confidence in the results) when one of these criteria were not included.
- High risk of bias (plausible bias that seriously weakens confidence in the results) when two or more criteria were missing.

Statistical analysis

Meta-analyses were to be conducted only if there were studies of similar comparison, reporting identical outcome measures. However, the studies included revealed considerable variations in study design, i.e. different time frames between implant installation and prosthetic loading, the use of different interpositional grafting material, dissimilar implants and prosthetic solutions, different implant lengths and widths, length of observation period, and type of outcome measures. Therefore, a well-defined meta-analysis was not applicable. Parametric data were expressed as mean and standard deviation (M [SD]). Statistical significance level was defined at $P = 0.05$.

RESULTS

Study selection

Article review and data extraction were performed according to the PRISMA flow diagram (Figure 1). A total of 135 titles were identified and 24 abstracts were reviewed. Full-text analysis included 18 articles and six studies were finally included in the present systematic review [23-28]. Two articles were included as the result of hand-searching [27,28].

Exclusion of studies

The reasons for excluding studies after full-text assessment were as follows: three studies were excluded [29-31] because the same patient sample with a 5-year observation period was reported in another included publication [25].

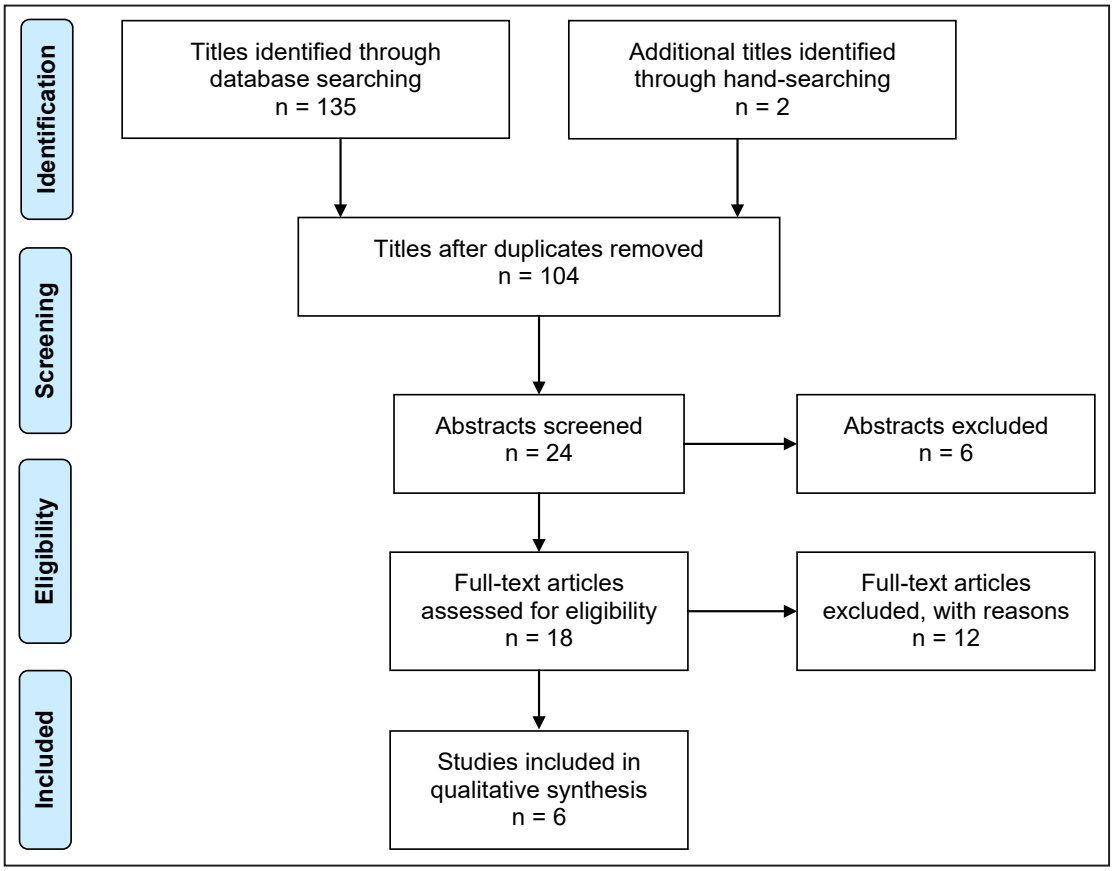

Figure 1. Flow diagram of studies selection according PRISMA guidelines.

Four studies were excluded [32-35] because the same patient sample with a 3-year observation period was reported in other publications included in the present systematic review [24,28]. Additionally, two studies were excluded [36,37] because the same patient sample with a 1-year observation period was reported in other publications included in the present systematic review [23,27]. Finally, three studies were excluded because the number of implants in the mandible was not specified [38] and a randomized controlled trial design was not used [39,40].

Study characteristics

The included studies in the present systematic review consisted of three randomized controlled trials with a split-mouth study design [23,24,26], two randomized controlled trials with a parallel group study design [25,28] and one randomized controlled multi-centre trial with a parallel group study design [27]. Partially edentulous patients with a residual vertical alveolar bone height of more than 5 mm above the mandibular alveolar canal were enrolled in the included studies of the present systematic review [23-28]. All studies were approved by the ethics committee and informed consent was obtained [23-28]. The CONSORT statement was followed in five studies [23-25,27,28]. The used power calculation of sample size was described in three studies [23-25]. The number and skills of the surgeons involved in the surgical procedure was described in five studies [23-25,27,28]. Patient demographics revealed certain dissimilarity [24] and smokers were not excluded in any of the included studies [23-28]. Detailed information about the outcome measures were specified in all studies [23-28]. Patients were treated in private practices [23-25,27,28] and in hospitals [23,24,27,28]. Pre- and postoperative antibiotic was prescribed in all the included studies [23-28]. The surgical procedure was performed in local anaesthesia [23-28]. Different types of interpositional grafting material was used involving anorganic bovine bone block (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) [24,25], and a collagenated block of cancellous equine bone (OsteoBiol, Sp-Block, Tecnoss, Giaveno, Italy) [23,26-28]. The grafted area was covered with a collagen resorbable barrier membrane (Bio-Gide, Geistlich Pharma, Wolhusen, Switzerland) [24,25] or (Sp-Block, OsteoBiol, Evolution, Tecnoss, Giaveno, Italy) [23,27,28]. The method used for randomization was described in all studies [23-28] involving a computer-generated restricted randomization list enclosed in sequentially numbered, identical, opaque, sealed envelopes [23-25,27,28] or flipping a coin [26].

All implants were inserted in local anaesthesia and standard length implants were inserted three months [23], four months [24,27,28], five months [25] or six months [26] after the sandwich osteotomy. Different implant system were used in the included studies (Table 2). The mean length of the inserted standard length implants was 10.8 mm [23], 10.4 mm [24], 10.8 mm [25], 10 mm [26], and 10.7 mm [28]. The resistance at implant insertion was recorded as < 25 Ncm or > 25 Ncm in five studies [23-25,27,28]. PIMBL was assessed using intraoral radiographs taken with the paralleling technique [23-25,27,28]. Number of patient drop-outs and reported reason was described in five of the included studies [23-25,27,28]. The 5-year follow-up examination involved 27 patients with short implants and 25 patients with standard length implants [25]. The 3-year follow-up examination involved 14 out of 15 patients [24]. The other 3-year follow-up examination had two drop-outs in each group [28]. The one-year follow-up examination after a split-mouth study design involved 19 patients, because one patient drop-out after implant placement [23]. The other one-year follow-up examination involved 20 patients with short implants and 19 patients with standard length implants [27]. Attempts to perform blind assessment of the postsurgical clinical registrations and radiographic was reported in all the included studies [23-28].

Outcome measures

The result of each outcome measure is presented first and then a short summary is finally provided. The results of the primary and secondary outcome measures are outlined in Table 3.

Primary outcome measures

Survival of suprastructures

The 5-year survival of suprastructures was 81.5% after placement of short implants compared to 80% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [25] (Table 3). Five prostheses failed in four patients rehabilitated with short implants due to early and late implant failure as well as fracture of the ceramic lining. Five prostheses failed in five patients rehabilitated with standard length implants due to early implant failure and fracture of the ceramic lining [25].

The 3-year survival of suprastructures was 93.3% after placement of short implants compared to 100% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [24]. One prosthesis failed in one patient rehabilitated with short implants [24].

The 3-year survival of suprastructures was 94.7% after placement of short implants compared to 90% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [28]. A crown failure occurred in one patient with short implants and two prosthesis failed in two patients with standard length implants due to graft failure and implant loss [28].

The 1-year survival of suprastructures was 100% after placement of short implants compared to 90% after the sandwich osteotomy and delayed placement of standard length implants [23] (P > 0.05). Two prosthesis failed in two patients rehabilitated with standard length implants due to graft failures [23].

The 1-year survival of suprastructures was 95% after placement of short implants compared to 94.7% (P > 0.05) after the sandwich osteotomy

Table 2. Implant systems used in the included studies

Study	Short implant	Standard length implant
Pistilli et al [23]	6 mm long implants with an implant width of 4 mm (Southern Implants, Irene, Centurion, South Africa) compared to at least	10 mm implants with an implant width of 4 mm (Southern Implants, Irene, Centurion, South Africa)
Esposito et al. [24]	5 mm long implants with an implant width of 6 mm (Rescue implant with internal connection, MegaGen Implant, Gyeongbuk, South Korea)	10 mm to 13 mm long implants with an implant width of 4 mm (EZ Plus with internal connection, MegaGen Implant, Gyeongbuk, South Korea)
Felice et al. [25]	6.6 mm long implants with an implant width of 4 mm (Nanotite, Biomet 3i, Palm Beach, Florida, USA)	9.6 mm or longer implants with an implant width of 4 mm (Nanotite, Biomet 3i, Palm Beach, Florida, USA)
Bernardi al. [26]	6 mm long implants with an implant width of 4.1 mm (ConicalActive, MACRODENTALCARE, Salero, Italy)	10 mm implants with an implant width of 3.9 mm (ConicalActive, MACRODENTALCARE, Salero, Italy)
Bolle et al. [27]	4 mm long transmucosal tapered implants with an implant width of 4 or 4.5 mm (Global D, TwinKon Universal)	10 mm long conical transmucosal tapered implants with an implant width of 4 or 4.5 mm (Global D, TwinKon Universal)
Gastaldi et al. [28]	5 mm long implants with an implant width of 5 mm (MegaGen Implant, Gyeongbuk, South Korea)	10 mm implants with an implant width of 5 mm (MegaGen Implant, Gyeongbuk, South Korea)

Table 3. Included studies assessing prosthetic rehabilitation in the partially edentulous atrophic posterior mandible with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard length implants (> 8 mm)

Study	Year of publication	Patient	Materials and methods					Primary outcome measures		Secondary outcome measures						
			VARH (mm)	Implants	Prosthetic solution	TBL (months)	LOP (months)	Survival (%)		Primary implant stability	PIMBL Mean (SD) mm				PPROM	Biological and technical complications
								ST	Implants							
Pistilli et al [23]	2013	20	5 - 7	SI: 41	Partial fixed prostheses	4	12	100	100	≤ 25 Ncm: 12%	Loading:	1-year:			1-month:	Number of complications: 0
											0.59 (0.05)	1.05 (0.06)			PPT: 20[a]	
				SLI: 47				90	93.6	≤ 2 5 Ncm: 9%	0.55 (0.05)	1.07 (0.06)			PPT: 0	Number of complications: 10[b]
Esposito et al. [24]	2014	15	5 - 7	SI: 26	Partial fixed prostheses	4	36	93.3	92.3	< 25 Ncm: 4%	Loading:	1-year:		3-year:	NR	Number of complications: 9
											0.3 (0.13)	1.20 (0.49)		1.44 (0.44)		
											0.22 (0.08)	1.20 (0.47)		1.63 (0.52)		Number of complications: 12
Felice et al. [25]	2014	30	7 - 8	SI: 60	Partial fixed prosthesis	4	60	81.5	91.7	< 25 Ncm: 7%	Loading:	1-year:	3-year:	5-year:	NR	Number of complications: 6
											1.37 (0.53)	1.79 (0.54)	1.98 (0.46)	2.24 (0.47)		
		30		SLI: 61				80	95.1	< 25 Ncm: 19%	1.21 (0.42	1.65 (0.42	2.43 (0.75)	3.01 (0.74)[c]		Number of complications: 25[d]
Bernardi al. [26]	2018	36	< 9	SI: 86	Cemented single crowns	NR	12	NR	94.2	NR	NR				NR	Number of complications: 3
				SLI: 84					84.5							Number of complications: 22[e]
Bolle et al. [27]	2018	20	5 - 6	SI: 43	Fixed prosthesis	4	12	95	95.7	< 25 Ncm: 14%	Loading:	4 months:	1-year:		NR	Number of complications: 2
											0.24 (0.11)	0.40 (0.12)	0.51 (0.16)			
		20		SLI: 38				94.7	97.4	< 25 Ncm: 10%	0.34 (0.08)[f]	0.52 (0.1)[g]	0.77 (0.21)[h]			Number of complications: 11[i]
Gastaldi et al. [28]	2018	20	5 - 7	SI: 32	Fixed prosthesis	4	36	94.7	96.9	< 25 Ncm: 3%	Loading:	1-year:	3-year:		NR	Number of complications: 8
											0.68 (0.27)	1.18 (0.29)	1.33 (0.38)			
		20		SLI: 31				90	93.5	< 25 Ncm: 19%	0.79 (0.25)	1.36 (0.28)	1.7 (0.36)[j]			Number of complications: 17[k]

[a]P-value <0.0001 (exact McNemar test), [b]P-value < 0.0078 (exact McNemar test), [c]P-value < 0.0001 (analysis of covariance), [d]P-value < 0.0001 (Fishers exact test), [e]P-value < 0.05 (Fishers exact test), [f]P-value = 0.001 (t-test), [g]P-value = 0.002 (t-test), [h]P-value < 0.001 (t-test), [i]P-value = 0.01 (Chi-square test), [j]P-value = 0.02 (t-test), [k]P-value = 0.008 (Fishers exact test).

LOP = length of observation period after implant loading; M = months; PIMBL = peri-implant marginal bone loss; PPROM = profesional and patient-reported outcome measures; PPT = patient preferred treatment; SD = standard deviation; SI = short implant; SLI = standard length implant; ST = suprastructures; TBL = time before loading; VARH = vertical alveolar ridge height.

and delayed placement of standard length implants [27]. One prosthesis failed in each group [27].

Summary

There were no statistically significant differences in the survival rate of suprastructures after prosthetic rehabilitation of the atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants.

Survival of implants

The 5-year implant survival rate was 91.7% after placement of short implants compared to 95.1% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [25] (Table 3). Five implants were lost in three patients rehabilitated with short implants compared to three implants in three patients rehabilitated with standard length implants [25].

The 3-year implant survival rate was 92.3% after placement of short implants compared to 96.7% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [24]. Two short implants in one patient were lost due to repeated abscesses and peri-implantitis. Five standard length implants could not be inserted in five patients due to inadequate vertical alveolar ridge height after the sandwich osteotomy. Instead, 7 mm and 8.5 mm implants were inserted [24]. However, one of the 8.5 mm implant was removed at the abutment connection due to loss of osseointegration [24].

The 3-year implant survival rate was 96.9% after placement of short implants compared to 93.5% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [28]. One short implant was lost in one patient, two years after loading and two standard length implants were lost in one patient due to lack of osseointegration and graft failure, respectively [28].

The 1-year implant survival rate was 100% after placement of short implants compared to 93.6% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [23]. Three standard length implants were lost in one patient. The patients were retreated and rehabilitated with three short implants [23].

The 1-year implant survival rate was 94.2% after placement of short implants compared to 84.5% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [26]. One short implant was lost due to lack of primary stability and four short implants were lost due to infections. Three standard length implants were lost due to lack of primary stability and ten standard length implants were lost due to infections [26].

The 1-year implant survival rate was 95.7% after placement of short implants compared to 97.4% (P > 0.05) after the sandwich osteotomy and delayed placement of standard length implants [27]. One short implant was lost in two patients. One standard length implant was lost in one patient. However, eight standard length implants could not be inserted due to inadequate vertical alveolar ridge height after the sandwich osteotomy [27].

Summary

There were no statistically significant differences in the long-term implant survival rate after prosthetic rehabilitation of the atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants.

Secondary outcome measures

Primary implant stability

The resistance at implant insertion was assessed in the study with a five year observation period after functional loading disclosing that four short implant in two patients were inserted with < 25 Ncm (P > 0.05) compared to 12 standard length implants in six patients [25] (Table 3).

The resistance at implant insertion was assessed in the study with a three year observation period after functional loading disclosing that one short implant was inserted with < 25 Ncm (P > 0.05) compared to three standard length implants in two patients [24].

The resistance at implant insertion was also assessed in the other study with a three year observation period after functional loading disclosing that one short implant was inserted with < 25 Ncm (P > 0.05) compared to six standard length implants in five patients [28].

The resistance at implant insertion was assessed in the study with an observation period of one year after functional loading disclosing that five short implants in four patients were inserted with < 25 Ncm (P > 0.05) compared to four standard length implants in three patients [23].

The resistance at implant insertion was also assessed in another study with an observation period of one year after functional loading disclosing that six short implants in four patients were inserted with < 25 Ncm (P > 0.05) compared to two standard length implants in two patients [27].

Summary

There were no statistically significant differences in the resistance at implant insertion after placement of short implants in the atrophic posterior mandible compared with the sandwich osteotomy and delayed placement of standard length implants.

Radiographic peri-implant marginal bone loss

The 5-year radiographic PIMBL was 2.24 (0.47) mm after placement of short implants compared to 3.01 (0.74) mm after the sandwich osteotomy and delayed placement of standard length implants [25] (Table 3). The difference was statistically significant ($P < 0.0001$). Moreover, a gradually statistically significant PIMBL was revealed for both treatment modalities ($P < 0.001$) [25].
The 3-year radiographic PIMBL was 1.44 (0.44) mm after placement of short implants compared to 1.63 (0.52) mm ($P > 0.05$) after the sandwich osteotomy and delayed placement of standard length implants [24]. However, a gradually statistically significant PIMBL was revealed for both treatment modalities ($P < 0.001$) [24].
The 3-year radiographic PIMBL was 1.33 (0.38) mm after placement of short implants compared to 1.7 (0.36) mm after the sandwich osteotomy and delayed placement of standard length implants [28]. The differences was statistically significant ($P = 0.02$). Moreover, a gradually statistically significant PIMBL was revealed for both treatment modalities ($P < 0.001$) [28].
The 1-year radiographic PIMBL was 1.05 (0.06) mm after placement of short implants compared to 1.07 (0.06) mm ($P > 0.05$) after the sandwich osteotomy and delayed placement of standard length implants [23]. However, a gradually statistically significant PIMBL was revealed for both treatment modalities ($P < 0.001$) [23].
The 1-year radiographic PIMBL was 0.51 (0.16) mm after placement of short implants compared to 0.77 (0.21) mm after the sandwich osteotomy and delayed placement of standard length implants [27]. The differences were statistically significant ($P < 0.001$). Moreover, a gradually statistically significant PIMBL was revealed for both treatment modalities ($P < 0.001$) [27].

Summary

The PIMBL seems to be significantly more pronounced after prosthetic rehabilitation of the atrophic posterior mandible with the sandwich osteotomy and delayed placement of standard length implants compared with the use of short implants.

Professional and patient-reported outcome measures

Professional and patient-reported outcome measures were assessed in one short-term study [23] (Table 3). All patients preferred prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants, one month after delivery of the definitive prostheses ($P < 0.0001$) [23].

Summary

A short-term study reported that all patients preferred prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared with the sandwich osteotomy and delayed placement of standard length implants.

Biological and technical complications

After five years of functional loading, five complications (temporary paraesthesia: 2, abutment screw loosening: 2, fracture of ceramic lining: 1) occurred after placement of short implants in five patients compared to 25 complications (fracture of Bio-Oss block: 3, temporary paraesthesia: 16, dehiscence: 4, abutment screw loosening: 1, fracture of ceramic lining: 1) after the sandwich osteotomy and delayed placement of standard length implants in 21 patients [25] (Table 3). The difference was statistically significant ($P < 0.0001$). Inadequate vertical alveolar ridge gain was archived in two of the three patients with fractured Bio-Oss block for placement of standard length implants. Instead, 6.6 mm short implants were inserted [25].
After three years of functional loading, nine complications (temporary paraesthesia: 3, abscesses: 3, abutments loosening: 3) occurred after placement of short implants in four patients compared to 12 complications (temporary paraesthesia: 11, dehiscence: 1) after the sandwich osteotomy and delayed placement of standard length implants in ten patients ($P > 0.05$) [24].
After three years of functional loading, nine complications (temporary paraesthesia: 8, fracture of ceramic lining: 1) occurred after placement of short implants in eight patients compared to 17 complications (intra-surgical haemorrhage: 1, temporary paraesthesia: 14, exposure of the osteotomized bone and mini-plate with graft failure: 1,

the piezo device perforated the lingual mucosa with wound dehiscence: 1, flap dehiscence after abutment connection with exposure of bone of loss of graft: 1) after the sandwich osteotomy and delayed placement of standard length implants in 17 patients. The difference was statistically significant (P = 0.008) [28].
After one year of functional loading, no complications occurred after placement of short implants compared to ten complications (temporary paraesthesia: 7, infection: 3) after the sandwich osteotomy and delayed placement of standard length implants in eight patients [23]. The difference was statistically significant (P < 0.0078) [23].
After one year of functional loading, three complications occurred after placement of short implants (temporary paraesthesia: 3) compared to 22 complications (temporary paraesthesia: 22) after the sandwich osteotomy and delayed placement of standard length implants. The difference was statistically significant (P < 0.05) [26].
After one year of functional implant loading, two complications (implant painful at percussion: 1, fracture of ceramic lining: 1) occurred after placement of short implants in two patients compared to 11 complications (pain, swelling and exudate: 1, temporary paraesthesia: 3, dehiscence: 2, fracture of the mandible: 1, the planed vertical ridge height not obtained: 4) after the sandwich osteotomy and delayed placement of standard length implants in nine patients. The difference was statistically significant (P = 0.01) [27].

Summary

The incidence of biological and technical complications after prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with the sandwich osteotomy and delayed placement of standard length implants was statistically significant higher compared with the use of short implants.

Quality assessment

The quality of the included studies is summarized in Table 4. Five of the included studies were considered low risk of bias [23-25,27,28], whereas one study was categorized as moderate risk of bias [26] due to missing information's about drop-outs.

DISCUSSION

The objective of the present systematic review was to test the hypothesis of no difference in the prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard length implants (> 8 mm). A total of six randomized controlled trials with low or moderate risk of bias fulfilled the inclusion criteria [23-28]. The two treatment modalities demonstrated high survival rate of suprastructures and implants after prosthetic rehabilitation of the partially edentulous atrophic posterior mandible. However, the sandwich osteotomy and delayed implant placement revealed statistically significant (P < 0.001) higher PIMBL as well as an increased incidence of biological and technical complications compared with the use of short implants. Moreover, patient's significantly favoured prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared to the sandwich osteotomy and delayed placement of standard length implants. However, only one long-term randomized controlled trial with a five year observation period after functional loading was included in the present systematic review. Moreover, the use of dissimilar implant designs, lengths, widths, surface topography and different interpositional grafting materials and healing periods of the grafting material and implants as well as various methodological confounding factors posed serious restrictions to review the literature in a quantitative systematic manner. Hence, the conclusions drawn from the results of the present systematic review should be interpreted with caution and further long-term randomized controlled trials involving donor site morbidity, an economic perspective as well as PPROM with the two treatment modalities are needed before definite conclusions can be provided about the beneficial use of short implants for prosthetic rehabilitation of the partially edentulous atrophic posterior mandible compared to the sandwich osteotomy and delayed placement of standard length implants.
Newly published systematic reviews and meta-analysis have revealed high survival rates of suprastructures and implants after prosthetic rehabilitation with short implants compared with various bone augmentation techniques and placement of standard length implants, which is in accordance with the result of the present systematic review [20,21,41]. However, the use of short implants is still considered controversial as a consequence of an unfavourable crown-to-implant ratio, increased risk of biological and technical complications due to potential overload and early implant failure owing to diminished bone-to-implant contact and PIMBL [12,18,42,43].

Table 4. Quality assessment of included studies

Study	Random selection in the population	Definition of inclusion and exclusion criteria	Report of losses to follow-up	Validated measurements	Statistical analysis	Risk of bias
Pistilli et al. [23]	Yes	Yes	Yes	Yes	Yes	Low
Esposito et al. [24]	Yes	Yes	Yes	Yes	Yes	Low
Felice et al. [25]	Yes	Yes	Yes	Yes	Yes	Low
Bernardi al. [26]	Yes	Yes	No	Yes	Yes	Moderate
Bolle et al. [27]	Yes	Yes	Yes	Yes	Yes	Low
Gastaldi et al. [28]	Yes	Yes	Yes	Yes	Yes	Low

An excessive crown-to-implant ratio is generally considered detrimental for long-term implant survival because of an increased stress concentration to the peri-implant crestal bone. Finite element model analysis of atrophic posterior partially edentulous mandible with a single 5 mm short implant in the first molar region demonstrate that traumatic occlusion and a high crown-to-implant ratio increased the stress concentrations [44]. Moreover, the crown-to-implant ratio has been reported to be a predictor for bone loss after placement of 6 mm implants in the atrophic posterior mandible [45]. However, previously published systematic reviews have reported that shorter implants supporting larger implant-supported restorations may have less PIMBL compared to standard implants [46-48]. Consequently, the influence of the crown-to-implant ratio on the implant failure and PIMBL seem inconsistent and further long-term studies assessing the crown-to-implant ratio after placement of short implants are needed.

The maintenance of a healthy peri-implant bone tissue is essential for the long-term success of short implants and standard length implants. Previous published systematic reviews have demonstrated that short implants had similar PIMBL as standard implants for implant-supported fixed prostheses [41,49]. This is in accordance with the result of the present systematic review, although there seem to be a significant higher PIMBL after prosthetic rehabilitation of the atrophic posterior mandible with the sandwich osteotomy and delayed placement of standard length implants compared with short implants. A successful implant treatment outcome may include marginal bone loss less than 1 to 1.5 mm during the first year after implant loading and less than 0.2 mm annually, which in turn corresponds to a maximum of 2.3 mm over 5 years [50]. In the present systematic review, only one study with an observation period of five years was included disclosing a radiographic PIMBL of 2.24 (0.47) mm after placement of short implants compared to 3.01 (0.74) mm after the sandwich osteotomy and delayed placement of standard length implants [25]. According to Albrektsson et al. [50] criterion of a successful implant treatment outcome, the two treatment modalities display high PIMBL after five years, and the sandwich osteotomy with delayed placement of standard length implants should not be considered as a successful implant treatment outcome. Consequently, further randomized controlled trials with an observation period of more than five years are needed to assess the long-term PIMBL with the two treatment modalities.

PPROM are essentially subjective and objective reports of patients' perceptions of their oral health status and its impact on their daily life or quality of life [51,52]. The influence of different prosthodontic rehabilitation options on improvement of orofacial aesthetics, chewing function, and oral health-related quality of life is an important prerequisite for selection of the best rehabilitation procedure for the patient with the highest treatment effect and lowest morbidity. In the present systematic review, patient-reported outcome measures were assessed in a split-mouth study by asking the patients about their preference between the two treatment modalities, one month after delivery of the definitive prostheses [23]. Previously published studies assessing PPROM after prosthetic rehabilitation with short implants compared with standard length implants in conjunction with a bone augmentation technique is scarce [53,54]. Assessment of patient-reported outcome measures after placement of short implants in the posterior part of the maxilla compared with the sinus elevation procedure and placement of standard length implants favoured treatment with short implants [53,54]. These results corroborate the findings of the included study of the present systematic review [23]. Thus, further studies assessing prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared with standard length implants in conjunction with a bone augmentation technique should contain an evaluation of donor site morbidity, an economic perspective, and PPROM.

The number of biological and technical complications as well as number of patients with complications was reported in all of the included studies of the present

systematic review [23-28]. A statistically significant higher number ($P < 0.05$) of biological and technical complications were reported after the sandwich osteotomy and delayed implant placement compared to the use of short implants [23,25-28]. These results are in accordance with previous published systematic reviews assessing prosthetic rehabilitation of partially edentulous atrophic posterior mandibles with short implants compared to standard length implants in conjunction with various bone augmentation techniques [5,20].

From a clinical and patient perspective, the results of the present systematic review indicates that prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants is preferable compared with the sandwich osteotomy and delayed implant placement.

CONCLUSIONS

The hypothesis of no difference in prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants (≤ 8 mm) compared with the sandwich osteotomy and delayed placement of standard length implants (> 8 mm) could neither be confirmed nor rejected due too insufficient evidence. High survival rate of suprastructures and implants was disclosed with short implants and the sandwich osteotomy with delayed implant placement indicating no differences in the prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with the two treatment modalities. However, the sandwich osteotomy and delayed implant placement demonstrated a statistically significant higher ($P < 0.001$) peri-implant marginal bone loss peri-implant marginal bone loss as well as more biological and technical complications compared to the use of short implants. Moreover, patient's significantly favoured prosthetic rehabilitation of the partially edentulous atrophic posterior mandible with short implants compared to the sandwich osteotomy and delayed implant placement. However, only one long-term randomized controlled trial with a 5-year observation period after functional loading was included in the present systematic review. Hence, the conclusions drawn from the results of this systematic review should be cautiously interpreted and further long-term randomized controlled trials involving assessment of donor site morbidity, an economic perspective as well as professional and patient-related outcome measures with the two treatment modalities are needed before definite conclusions can be provided about the beneficial use of short implants for prosthetic rehabilitation of the posterior mandible compared with the sandwich osteotomy and delayed implant placement.

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doi: 10.5037/jomr.2018.9202

Appendix 1. Embase search until the 9th of May, 2018

ID	Search terms	n, hits
1	'mandible'/exp	46098
2	((atrophic OR posterior OR edentulous*) NEAR/3 mandible*):ti,ab,kw	2493
3	#1 OR #2	47103
4	'face surgery'/exp	48583
5	(mandibular NEAR/3 prosthes* NEAR/3 implantation*):ti,ab,kw	4
6	'mandible osteotomy'/exp	2143
7	'tooth implant'/exp	8355
8	((dental OR oral OR short* OR long* OR standard) NEAR/3 implant*):ti,ab,kw	25882
9	((dental OR oral) NEAR/3 (rehabilitat* OR prosth*)):ti,ab,kw	7361
10	((mandibular OR sandwich) NEAR/3 osteotom*):ti,ab,kw	1611
11	mandibulo*:ti,ab,kw OR mandibule*:ti,ab,kw OR hemimandibulectom*:ti,ab,kw	2567
12	#4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11	85488
13	#3 AND #12	6965
14	'alveolar ridge augmentation'/exp	899
15	((alveolar OR vertical OR mandibular) NEAR/3 (bone OR ridge) NEAR/3 augmentation):ti,ab,kw	1119
16	#14 OR #15	154
17	#13 AND #16	13
18	#17 AND ('randomized controlled trial'/de OR 'randomized controlled trial (topic)'/de)	401249
19	(((random* OR control?ed OR crossover OR 'cross over' OR blind* OR mask*) NEAR/3 (trial*1 OR study OR studies OR analy*)):ti,ab,kw) OR rct:ti,ab,kw	351268
20	placebo*:ti,ab,kw OR 'single blind*':ti,ab,kw OR 'double blind*':ti,ab,kw OR 'triple blind*':ti,ab,kw	213268
21	((single OR double OR triple) NEAR/2 (blind* OR mask*)):ti,ab,kw	213013
22	#19 OR #20 OR #21	624799
23	#17 AND #22	9
24	#18 OR #23	18

Appendix 2. PubMed search until the 9th of May, 2018

ID	Search terms	n, hits
1	"Mandibular Prosthesis Implantation"[Mesh]	120
2	"Mandibular Osteotomy"[Mesh]	357
3	"Dental Implants"[Mesh]	20157
4	dental implant*[TW] OR dental prosthe*[TW] OR oral implant*[TW] OR oral prosthe*[TW] OR oral rehabilitat*[TW] OR dental rehabilitat*[TW] OR mandibular osteotom*[TW] OR mandibulo*[TW] OR mandibule*[TW] OR hemimandibulectom*[TW] OR sandwich osteotom*[TW] OR short implant*[TW] OR long implant*[TW] OR standard implant*[TW] OR standard lenght implant*[TW]	51670
5	"Mandibular Prosthesis Implantation"[Mesh] OR "Mandibular Osteotomy"[Mesh] OR "Dental Implants"[Mesh] OR dental implant*[TW] OR dental prosthe*[TW] OR oral implant*[TW] OR oral prosthe*[TW] OR oral rehabilitat*[TW] OR dental rehabilitat*[TW] OR mandibular osteotom*[TW] OR mandibulo*[TW] OR mandibule*[TW] OR hemimandibulectom*[TW] OR sandwich osteotom*[TW] OR short implant*[TW] OR long implant*[TW] OR standard implant*[TW] OR standard lenght implant*[TW]	51747
6	"Mandible"[Mesh]	52262
7	atrophic mandible*[TW] OR posterior mandible*[TW] OR edentulous mandible*[TW]	2128
8	atrophic mandible*[TW] OR posterior mandible*[TW] OR edentulous mandible*[TW] OR "Mandible"[Mesh]	53143
9	(("Mandibular Prosthesis Implantation"[Mesh] OR "Mandibular Osteotomy"[Mesh] OR "Dental Implants"[Mesh] OR dental implant*[TW] OR dental prosthe*[TW] OR oral implant*[TW] OR oral prosthe*[TW] OR oral rehabilitat*[TW] OR dental rehabilitat*[TW] OR mandibular osteotom*[TW] OR mandibulo*[TW] OR mandibule*[TW] OR hemimandibulectom*[TW] OR sandwich osteotom*[TW] OR short implant*[TW] OR long implant*[TW] OR standard implant*[TW] OR standard lenght implant*[TW])) AND (atrophic mandible*[TW] OR posterior mandible*[TW] OR "Mandible"[Mesh] OR edentulous mandible*[TW])	8007
10	"Alveolar Ridge Augmentation"[Mesh]	3683
11	Alveolar Ridge Augmentation[TW] OR Alveolar bone Augmentation[TW] OR vertical ridge augmentation[TW] OR vertical bone augmentation[TW] OR mandibular bone augmentation[TW]	3932
12	(((((("Alveolar Ridge Augmentation"[Mesh]) OR Alveolar Ridge Augmentation[TW]) OR Alveolar bone Augmentation[TW]) OR vertical ridge augmentation[TW]) OR vertical bone augmentation[TW]) OR mandibular bone augmentation[TW]	3932
13	((((("Mandibular Prosthesis Implantation"[Mesh] OR "Mandibular Osteotomy"[Mesh] OR "Dental Implants"[Mesh] OR dental implant*[TW] OR dental prosthe*[TW] OR oral implant*[TW] OR oral prosthe*[TW] OR oral rehabilitat*[TW] OR dental rehabilitat*[TW] OR mandibular osteotom*[TW] OR mandibulo*[TW] OR mandibule*[TW] OR hemimandibulectom*[TW] OR sandwich osteotom*[TW] OR short implant*[TW] OR long implant*[TW] OR standard implant*[TW] OR standard lenght implant*[TW])) AND (atrophic mandible*[TW] OR posterior mandible*[TW] OR "Mandible"[Mesh] OR edentulous mandible*[TW]))) AND ((((((("Alveolar Ridge Augmentation"[Mesh]) OR Alveolar Ridge Augmentation[TW]) OR Alveolar bone Augmentation[TW]) OR vertical ridge augmentation[TW]) OR vertical bone augmentation[TW]) OR mandibular bone augmentation[TW])	671
14	((random*[TW] OR controlled[TW] OR crossover[TW] OR cross-over[TW] OR blind*[TW] OR mask*[TW]) AND (trial OR trials OR study OR studies OR analyz*)) OR rct[TW] OR ((singl*[TW] OR doubl*[TW] OR tripl*[TW]) AND (blind[TW] OR mask[TW])) OR placebo[Text Word]	1487535
15	"Controlled Clinical Trial"[Publication Type]	547405
16	"Controlled Clinical Trials as Topic"[Mesh]	122766
17	(((((("Controlled Clinical Trial"[Publication Type] OR "Controlled Clinical Trials as Topic"[Mesh])) OR (((random*[TW] OR controlled[TW] OR crossover[TW] OR cross-over[TW] OR blind*[TW] OR mask*[TW])) AND (trial OR trials OR study OR studies OR analyz*))) OR rct[TW]) OR (((singl*[TW] OR doubl*[TW] OR tripl*[TW])) AND (blind[TW] OR mask[TW]))) OR placebo[TW]	1488014
18	((((((("Mandibular Prosthesis Implantation"[Mesh] OR "Mandibular Osteotomy"[Mesh] OR "Dental Implants"[Mesh] OR dental implant*[TW] OR dental prosthe*[TW] OR oral implant*[TW] OR oral prosthe*[TW] OR oral rehabilitat*[TW] OR dental rehabilitat*[TW] OR mandibular osteotom*[TW] OR mandibulo*[TW] OR mandibule*[TW] OR hemimandibulectom*[TW] OR sandwich osteotom*[TW] OR short implant*[TW] OR long implant*[TW] OR standard implant*[TW] OR standard lenght implant*[TW])) AND (atrophic mandible*[TW] OR posterior mandible*[TW] OR "Mandible"[Mesh] OR edentulous mandible*[TW]))) AND ((((((("Alveolar Ridge Augmentation"[Mesh]) OR Alveolar Ridge Augmentation[TW]) OR Alveolar bone Augmentation[TW]) OR vertical ridge augmentation[TW]) OR vertical bone augmentation[TW]) OR mandibular bone augmentation[TW]))) AND ((((((("Controlled Clinical Trial"[Publication Type] OR "Controlled Clinical Trials as Topic"[Mesh])) OR (((random*[Text Word] OR controlled[Text Word] OR crossover[Text Word] OR cross-over[Text Word] OR blind*[Text Word] OR mask*[Text Word])) AND (trial OR trials OR study OR studies OR analyz*))) OR rct[Text Word]) OR (((singl*[Text Word] OR doubl*[Text Word] OR tripl*[Text Word])) AND (blind[Text Word] OR mask[Text Word]))) OR placebo[Text Word])	80

Appendix 3. Cochrane Library search until the 9th of May, 2018

ID	Search terms	n, hits
1	MeSH descriptor: [Mandible] explode all trees	1595
2	(atrophic or posterior or edentulous) near/3 mandible:ti,ab,kw (Word variations have been searched)	312
3	#1 or #2	1680
4	(mandible or mandibular or sandwich) near/3 osteotomy:ti,ab,kw (Word variations have been searched)	110
5	(dental or oral or short or long or standard) near/3 implant:ti,ab,kw (Word variations have been searched)	2282
6	(dental or oral) near/3 (rehabilitation or prostheses):ti,ab,kw (Word variations have been searched)	1528
7	mandibulotomy or mandibuloplasty or mandibulectomy or hemimandibulectomy:ti,ab,kw (Word variations have been searched)	13
8	#4 or #5 or #6 or #7	2875
9	#3 and #8	455
10	MeSH descriptor: [Alveolar Ridge Augmentation] explode all trees	302
11	((alveolar or vertical or mandibular) near/3 (bone or ridge) near/3 augmentation):ti,ab,kw (Word variations have been searched)	347
12	#10 or #11	347
13	#9 and #12	38
14	#13 [in Trials]	37
15	(random* or control* or crossover or cross-over or blind* or mask*) near/3 (trial*1 or study or studies or analy*):ti,ab,kw (Word variations have been searched)	477936
16	placebo* or single-blind* or double-blind* or triple-blind*:ti,ab,kw (Word variations have been searched)	322115
17	(single or double or triple) near/2 (blind* or mask*):ti,ab,kw (Word variations have been searched)	258566
18	#15 or #16 or #17	611477
19	#13 and #18	7
20	#14 or #19	37