Horizontal Ridge Augmentation in Conjunction with or Prior to Implant Placement in the Anterior Maxilla: A Systematic Review

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Purpose: *To systematically review clinical studies examining the survival and success rates of implants in horizontal ridge augmentation, either prior to or in conjunction with implant placement in the anterior maxilla.* ***Materials and Methods:*** *A literature search was undertaken up to September 2012 including clinical studies in English with ≥ 10 consecutively treated patients and a mean follow-up of at least 12 months. Two reviewers screened the pertinent articles and extracted the data. Key words focused on the outcome parameters (implant success, implant survival, horizontal bone gain, and intra- and postoperative complications) in studies utilizing either a simultaneous approach (ridge augmentation performed at the time of implant placement) or a staged approach (ridge augmentation performed prior to implant placement) were analyzed.* ***Results:*** *A total of 13 studies met the inclusion criteria, with 2 studies in the simultaneous group and 11 studies in the staged group. In the simultaneous group, survival rates of implants were 100% in both studies, with one study also reporting a 100% implant success rate. No data on horizontal bone gain were available. In the staged group, success rates of implants placed in horizontally augmented ridges ranged from 96.8% to 100% (two studies), and survival rates ranged from 93.5% to 100% (five studies). However, follow-up periods differed widely (up to 4.1 years). Mean horizontal bone gain determined at reentry (implant placement) ranged from 3.4 to 5.0 mm with large overall variations (0 to 9.8 mm, five studies). Intraoperative complications were not reported. Postsurgical complications included mainly mucosal dehiscences (five studies), and, occasionally, complete failures of block grafts were described in one study.* ***Conclusions:*** *Staged and simultaneous augmentation procedures in the anterior maxilla are both associated with high implant success and survival rates. The level of evidence, however, is better for the staged approach than for the simultaneous one.* Int J Oral Maxillofac Implants 2014;29(suppl):14–24. doi: 10.11607/jomi.2014suppl.g1.1

Key words: *anterior maxilla, bone gain, esthetic zone, horizontal ridge augmentation, implant success, implant survival, surgical complications*

Implant therapy has become an integral part of clinical dentistry, with ever-increasing numbers of patients seeking such treatment. In conjunction with this development, patient awareness, particularly regarding time and esthetics has risen. Many patients have expectations of a short treatment time and perfect results, posing a significant challenge to the clinician and dental technician alike.

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Whether a low or high smile line is present, many patients consider their maxillary anterior teeth to be one of their most important esthetic facial features.[1,2] In addition, many patients present with tissue deficiencies in the anterior maxilla, either following traumatic tooth loss or periodontal or endodontic disease. Malformation and tumors are less frequently the cause of tissue loss in the anterior maxilla. Tissue deficiencies may include deficits of soft tissue (alveolar mucosa) and/or hard tissue (alveolar bone). Bone deficiencies of the alveolar process may be categorized as vertical or horizontal deficits, or combinations thereof. Hard and/or soft tissue defects may lead to functional, structural, or esthetic compromises in the final prosthesis.[3] Various classifications of bone resorption or alveolar ridge configurations have been proposed in relation to treatment planning in dental and maxillofacial implantology.[3–6]

A plethora of surgical techniques have been described in the last four decades regarding reconstruction of deficient alveolar bone for supporting dental implants, eg, particulate graft augmentation, block graft augmentation, ridge splitting or ridge expansion, and distraction osteogenesis.[7] Materials used for the reconstruction of alveolar bone include autogenous bone, allogeneic bone, xenografts, alloplasts, bone promoting proteins, barrier membranes, titanium meshes and foils, fixation screws, pins and plates, and bone transportation devices.[7]

Alveolar ridge rebuilding can be undertaken at different time points during treatment, and is generally categorized as simultaneous or staged. In the staged approach, the alveolar bone is first reconstructed in an initial surgery, and implant placement is then carried out 2 to 6 months later.[8] In contrast, in the simultaneous approach, implant placement and alveolar ridge reestablishment are undertaken in the same surgery.[9] The simultaneous approach is obviously the preferred technique by the patient and clinician alike, since it reduces treatment time and cost. However, if the residual bone volume precludes primary implant stability, or results in inadequate prosthodontic implant positioning, the staged approach is recommended. In the anterior maxilla (esthetic zone), a third component must be considered in the treatment decision process: the esthetic expectations of the patient and his/her esthetic profile (level of smile line, gingival biotype, soft tissue deficit, size of edentulous gap, and bone level at adjacent teeth).

Treatment planning and precise scheduling of tooth extraction and implant placement are important issues to reduce healing periods, morbidity of the patient, and to create the fewest number of surgical interventions. The risk of inadvertent bone loss is particularly high in the anterior maxilla which is commonly known to exhibit a thin (or even partially absent) labial bone plate.[10] Since this bone plate mainly consists of the so-called bundle bone, associated with the presence of a non-ankylotic tooth together with a viable periodontal ligament, removal of the root or post-traumatic root ankylosis will disturb this functional unit, resulting in considerable resorption of the labial bone plate. As a consequence, many cases referred for implant treatment in the anterior maxilla present with horizontal bone deficiencies that requires horizontal bone augmentation.

While previous systematic reviews of clinical studies on alveolar ridge reconstruction have pooled data from different jaw locations (maxilla, mandible, anterior sites, posterior sites)[11–17] the present systematic review will focus on the anterior maxilla, ie, the esthetic zone. The review aims to report success and survival rates of implants placed in conjunction with simultaneous or staged horizontal bone augmentation in patients with single or multiple gaps in the anterior maxilla. In addition, data about gain of horizontal bone width and intra- and postsurgical complications are collected and presented.

MATERIALS AND METHODS

Inclusion and exclusion criteria were defined before beginning the study by the authors. Criteria included study type, number of treated patients, type and area of intervention, outcome parameters and follow-up period.

Study Type

Only clinical studies in humans and published in English were accepted for this systematic review. Experimental studies, case reports, review articles, technical notes, and expert opinion articles were excluded. The clinical study had to be performed in a minimum of 10 patients, irrespective of the number of treated patients for a given therapeutic option.

Type and Area of Intervention

Horizontal bone augmentation had to be carried out in the anterior maxilla (esthetic zone), defined as the area from the right first premolar to the left first premolar. Studies reporting vertical ridge augmentation, distraction osteogenesis, ridge expansion or splitting techniques, and alveolar socket preservation were excluded for this review. Clinical studies on horizontal bone augmentation in patients with congenital malformations, after tumor resection, or following osteoradionecrosis were also excluded, since treatment and outcome in these cases are not comparable.

Outcome Parameters and Follow-Up Period

Studies were included provided they reported data about implant success (with specified success criteria) and/or survival rates of implants that were inserted either in conjunction with horizontal bone augmentation (simultaneous approach) or after horizontal bone augmentation (staged approach), and that the implants had been loaded for a minimum period of one year. Additionally, studies describing the horizontal bone gain at reentry time or reporting intra- and postoperative complications were also included, irrespective of the follow-up period or loading period of implants (Table 1).

Search Strategy

PubMed using Endnote X4 served as the source for searching studies up to September 2012. Articles were selected using the following search terms: "maxilla"

Table 1 Systematic Search Strategy

Focus question: Does horizontal ridge augmentation in conjunction with or prior to implant placement in the anterior maxilla influence the implant outcome?	
Search strategy	
Population	Patients presenting with single/multiple gaps in the anterior maxilla with deficiency of ridge width
Intervention or exposure	Horizontal ridge augmentation in the anterior maxilla
Comparison	Simultaneous versus staged approach
Outcome	1) Success (parameters) ≥ 1 year 2) Survival ≥ 1 year 3) Complications: intraoperative/postoperative (up to abutment connection)/late complications 4) Gain of bone width
Search combination	"maxilla" AND "implants" AND "augmentation" AND "human" NOT "sinus". This search was combined with: "lateral", "horizontal", "esthetics", "simultaneous," and "staged"
Database search	
Electronic	PubMed (English)
Selection criteria	
Inclusion criteria	Horizontal ridge augmentation and implant placement Clinical studies Anterior maxilla (first premolar–first premolar)
Exclusion criteria	Animal studies Case reports Reviews Patients with congenital malformations Studies < 10 patients < 1 year of follow-up (success and survival) Pooled data (extraction of detailed information is impossible)

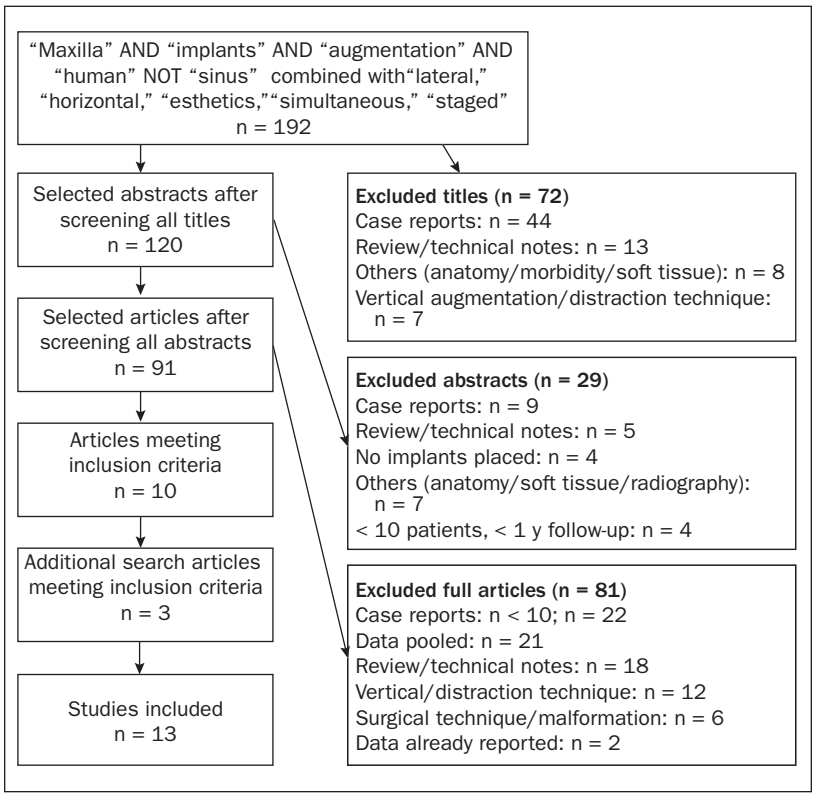


Fig 1 Search strategy.

AND "implants" AND "augmentation" AND "human" NOT "sinus". This search was combined with the following search terms: "lateral", "horizontal", "esthetics", "simultaneous," and "staged". Duplicates were removed from the search. The authors UK and TvA individually screened the titles of articles based on the inclusion criteria. Following this, the remaining abstracts were selected and disagreement was solved by discussion. If title or abstract did not allow a clear decision about the inclusion criteria, the full article was obtained. In addition, related articles in PubMed and in the private library of TvA were screened and led to another three publications which met the inclusion criteria. Based on the pre-selection, the full text articles were then analyzed as to whether they met the inclusion criteria and mutual agreement on the final selection of studies was obtained (Fig 1).

Data Extraction

The two reviewers independently extracted the data of the publications included. In studies reporting pooled data of various jaw areas but providing detailed information for sites in the anterior maxilla, data were extracted and recalculated for those sites.

The following information was collected from the publications:

- Number of treated patients
- Material/technique used for horizontal ridge augmentation
- Width of alveolar bone before and after augmentation
- Intra- and postoperative complications
- Interval between augmentation and reentry
- Width of alveolar bone at reentry
- Number of inserted implants
- Follow-up period of loaded implants
- Success rate of loaded implants (with success criteria) in the augmented ridge
- Survival rate of loaded implants in the augmented ridge

RESULTS

The literature search yielded a total of 192 publications within the specified search terms. Seventy-two studies were excluded after screening the titles, and 29 did not meet the inclusion criteria after reading the abstracts. Overall, 91 full articles were analyzed but only 10 articles fulfilled the inclusion criteria for data extraction (Fig 1). Based on an additional search, three articles were included in this review. The results are presented separately for the simultaneous and the staged approaches (Tables 2 and 3).

Simultaneous Approach

Two prospective cohort studies[18,19] met the inclusion criteria for this review, reporting on a total of 35 patients, investigating implant placement in conjunction with simultaneous horizontal ridge augmentation in the anterior maxilla (Table 2). In one study, peri-implant horizontal ridge augmentation was performed with locally harvested bone chips, deproteinized bovine bone mineral (DBBM) particles, and collagen membrane coverage.[18] In the other study, DBBM particles and a titanium-reinforced expanded polytetrafluoroethylene (ePTFE) membrane with non-resorbable pins were utilized for the same purpose.[19] Buser et al[18] reported an implant success rate of 100% (follow-up period three years), and both studies described a survival rate of 100% for the follow-up period (Table 2). No data were reported on horizontal bone gain in these two studies. Neither intraoperative nor postoperative complications occurred in one study,[19] whereas the other study provided no information about complications (Table 2, Fig 2a).[18]

Staged Approach

A total of 11 studies (3 cohort prospectives,[20–22] 6 cohort retrospectives,[23–28] 1 prospective comparative,[29] and 1 randomized clinical trial[30]) were identified, with a total of 353 patients in whom horizontal bone augmentation was performed prior to implant placement. Various augmentation techniques were reported including the use of autogenous, allogeneic, or xenogenic bone with or without membrane coverage (Table 3, Fig 2b). The majority of studies utilized autogenous bone blocks from either the symphysis or retromolar area.

With regard to success rates of implants placed into horizontally augmented ridges in the anterior maxilla, two studies with a total of 91 implants reported a success rate of 100% in one study with a mean follow-up period of 1 and 4.1 years[25,26] and a success rate of 96.8% in the other study with a mean follow-up of 37 months.[23] The latter study described marginal bone loss in 3 out of 31 implants in the first year (Table 3).

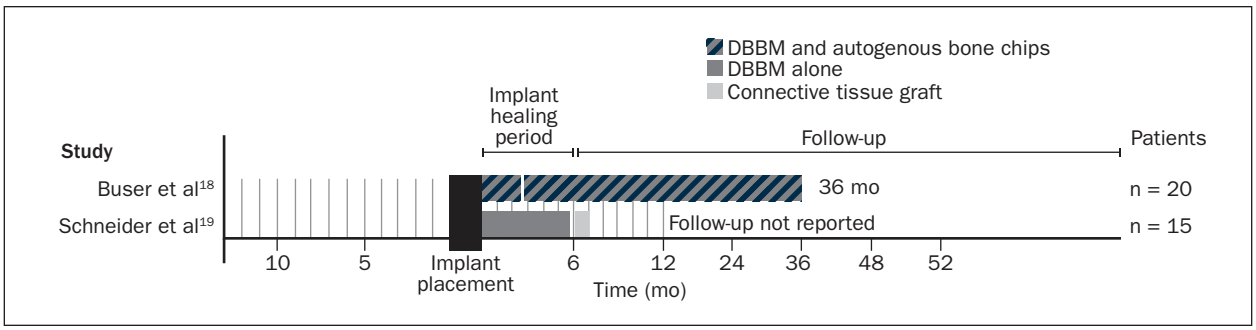
Five studies reported the survival rates of implants placed into horizontally augmented ridges in the anterior maxilla.[23,25,26,28,29] Three studies reported a survival rate of 100%.[23,25,26] In the comparative study by Meijndert et al,[29] survival rates differed for the three treatment options: While implants placed into sites augmented with chin bone presented a survival rate of 100%, implants placed into sites augmented with DBBM had a survival rate of 93.5% within a follow-up period of 1 year. In the study by Nissan et al (2012),[28] the survival rate was 96.8% after a mean follow-up period of 4 years (Table 3).

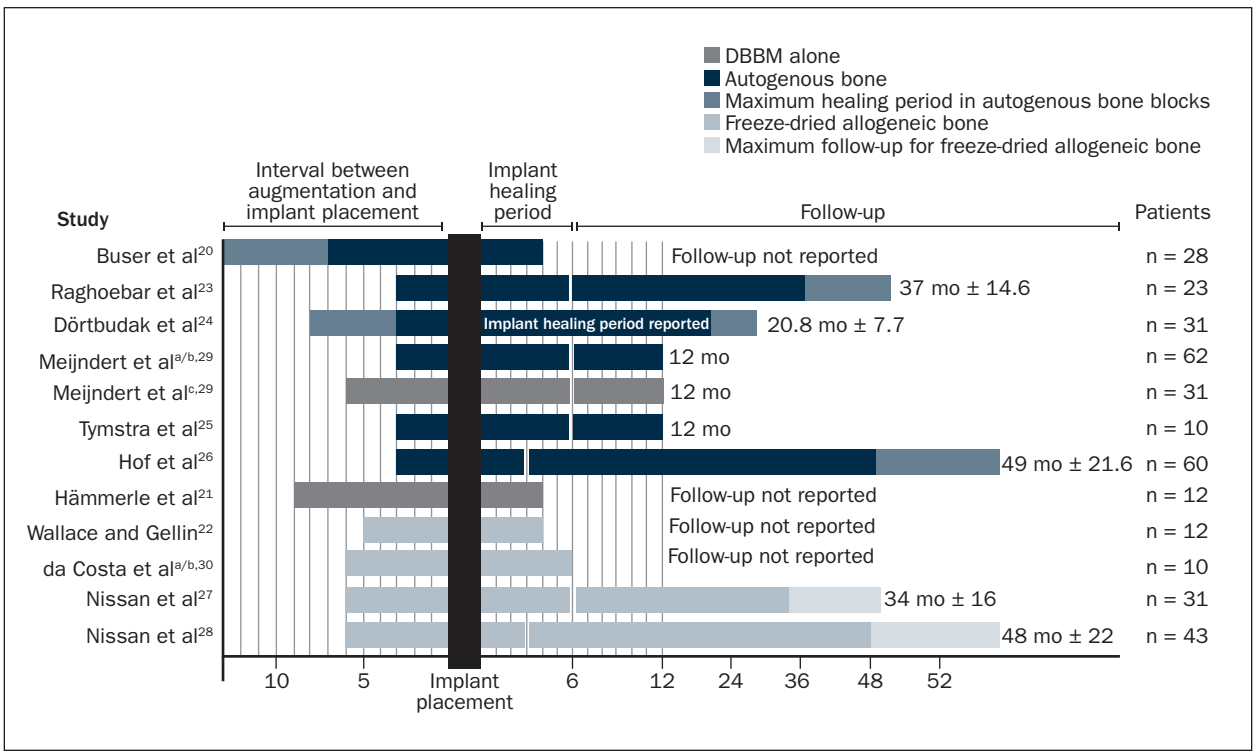
Five studies reported on horizontal bone gain assessed at the time of reentry (implant placement).[20–22,27,30] Mean intervals between augmentation and reentry ranged from 5 to 13 months (Fig 2). The actual horizontal bone gain varied between 0 and 9.8 mm in those five studies with mean values of 3.4 mm, 3.6 mm, 4.5 mm, 4.6 mm/2.15 mm (study comparing allogeneic bone blocks with and without autogenous bone marrow aspirate), and 5 mm, respectively. Two additional studies evaluated graft resorption between augmentation and reentry with intervals ranging from 3 to 8 months.[23,24] One study reported a mean loss of 6% (range 0% to 20%), with greater resorption observed in grafts from the tuberosity.[23] In the other study,[24] mean graft resorption was 0.79 mm (range 0 to 2 mm). Cases with 3 to 4 months of graft healing presented less resorption (0.33 mm) than cases with 5 to 8 months of graft healing (1.22 mm).[24]

Table 2 Results of Studies Using Simultaneous Approach

Author	Study type	Patients	Techniques	Implant healing period	Width before grafting (mm)	Width after grafting*
Buser et al[18]	Cohort, prospective	20	Locally harvested autogenous bone chips, DBBM and collagen membrane	8–12 wk	< 6	N/A
Schneider et al[19]	Cohort, prospective	16	DBBM and titanium-reinforced ePTFE membrane (secured with 1–2 nonresorbable pins), connective tissue graft after 6 months	6 mo	< 3	N/A*

*Authors reported combined soft and hard tissue width, data extraction not possible.
N/A: not reported or unable to be extracted; PES: Pink Esthetic Score, WES: White Esthetic Score; mPI: modified Plaque Index; mSBI: modified Sulcus Bleeding Index; PD: probing depth; KM: keratinized mucosa; DIM: distance of mucosal margin to implant shoulder; DIB: distance of bone to implant contact.





Figs 2a and 2b Characteristics of studies on *(a)* simultaneous and *(b)* staged approaches.

Regarding surgical complications, two studies reported that no intraoperative complications occurred (Table 3).[23,24] All other studies did not provide such information. With respect to postoperative complications, five studies described such incidents.[20,23,24,27,28] Most frequently, postsurgical complications included soft tissue dehiscences with exposure of grafts. Complete failure of two block grafts was reported by Nissan et al.[27] Dörtbudak et al[24] described spontaneous healing of a fistula after removal of necrotic bone.

Width at follow-up*	Bone width gain*	Intraoperative complications	Postoperative complications	Follow-up after loading	Implants at follow-up	Implant success	Implant survival
N/A	N/A	N/A	N/A	3 y	20	100% (clinical examination: mPI, mSBI, PD, KM DIM, DIB, PES, WES)	100%
N/A*	N/A*	None	None	1 yr	15	N/A	100%

The same authors[24] also reported wound dehiscences of donor sites as well as transient and permanent tooth sensitivity changes in the anterior mandible in two patients. No postoperative complications occurred in three studies,[21,22,29] but no gain of bone at all was reported for one case[21] and significant allogeneic block resorption was observed also in one case.[22] No information regarding postoperative complications was found in the remaining studies.[25,26,30]

DISCUSSION

Bone deficiency in the anterior maxilla prevents primary implant stability or results in an inadequate implant position with compromised esthetics or function.[1] Therefore, horizontal ridge augmentation is a prerequisite before or during implant placement. The present systematic review evaluated clinical studies reporting data about implant success, implant survival, gain of bone width, and intra- and postoperative complications, in conjunction with horizontal bone augmentation limited to the anterior maxilla. The decision to focus the systematic review on the esthetic zone was based on three facts:

The anterior maxilla is the most challenging area regarding esthetics in implant dentistry.

Many, if not most, cases in the anterior maxilla require horizontal ridge augmentation due to partial or complete loss of the facial bone plate following tooth extraction or tooth loss.

To the knowledge of the authors, no such systematic review has been carried out before.

However, limiting the search to the anterior maxilla resulted in a low number of relevant clinical studies fulfilling the inclusion criteria. Additionally, in order to attain some homogeneity of included articles, the surgical approach used to improve alveolar ridge width was narrowed down to horizontal bone augmentation, thus excluding other surgical techniques like immediate implant placement with socket grafting or implant placement after ridge expansion, ridge splitting, or distraction osteogenesis. Also, the majority of excluded clinical studies could not be taken into consideration because they either report single cases, describe technical notes of alveolar ridge reconstruction, or the study material comprised maxillary and mandibular anterior and posterior cases with pooled data, thus not allowing for data extraction.

Since timing, surgical technique, and geometry of defects differ in simultaneous versus staged horizontal bone augmentation, studies were grouped accordingly and will be discussed separately.

Simultaneous Approach

The fact that only two studies could be analyzed in this group calls for further clinical research focusing on simultaneous peri-implant horizontal ridge augmentation in the anterior maxilla. While many studies evaluate the vertical coverage of exposed implant surfaces using bone augmentation, they lack information about the horizontal bone dimension on the facial aspect. Various authors have highlighted the importance of the thickness of the facial bone showing that a minimum of 2 mm of facial bone is required to avoid vertical buccal bone resorption.[31–33] Although both studies included in this review[18,19] reported an implant survival rate of 100%, no firm conclusions can be drawn, with a total of only 35 implants. The same refers to the success rate, which was only evaluated in one study with 20 implants, all of them categorized as successful.[18]

Staged Approach

For this review, 11 studies with a total of 353 patients investigated outcome parameters after staged bone augmentation, in a time period of 15 years of research. The overall success rates range between 96.8% and 100%, and survival rates range from 93.5% to 100%. The data reported by Meijndert et al[29] are rather interesting since the authors performed a prospective comparative study on staged horizontal ridge augmentation in the anterior maxilla. While implants placed into sites augmented with chin bone blocks presented a success rate of 100%, those inserted into sites augmented with DBBM particles had a success rate of 93.5%.

Table 3 Results of Studies Using Staged Approach

Author	Study type	Patients	Techniques	Interval augmentation and implant placement	Width before grafting (mm)	Width after grafting (mm)
Buser et al[20]	Cohort, prospective	28 (total = 40 patients; data extracted from 28 patients with 40 anterior maxillary sites)	Autogenous bone block graft from chin or retromolar area, fixation with bone screw. Surrounding spaces filled with autogenous bone chips. Coverage with ePTFE-membrane.	7–13 mo	3.6 (2–4.5)	N/A
Raghoebar et al[23]	Cohort retrospective	23 (+4)	Group A, Monocortical autogenous grafts (12× symphysis, 7× retromolar, 4× tuberosity), fixation with titanium plates or screws. Group B, 4 cases, alveolus filled with bone from tuberosity	3 mo	< 2	7.3 (range, 7–8) (results combined groups A and B)
Dörtbudak et al[24]	Cohort, retrospective	31	Autogenous block grafts from chin fixated with titanium miniscrew	3–8 mo	< 4	N/A
Meijndert et al[29]	Prospective comparative	93	Group A, chin bone/titanium screw (n = 31) Group B, chin bone/titanium screw + collagen membrane (n = 31) Group C, DBBM + collagen membrane (n = 31)	Groups A and B, 3 mo; Group C, 6 mo	N/A	N/A
Tymstra et al[25]	Cohort, retrospective	10	Autogenous chin bone blocks	3 mo	N/A	N/A
Hof et al[26]	Cohort, retrospective	60	Autogenous bone block grafts with screw fixation	Minimum 3 mo	< 6	N/A
Hämmerle et al[21]	Cohort, prospective	12	Blocks or granules of DBBM + collagen membrane (fixed with resorbable pins)	9–10 mo	3.2 ± 0.9 (1.5–4.5)	N/A
Wallace and Gellin[22]	Cohort, prospective	12	Cancellous freeze-dried allograft bone blocks fixed with 2 bone screws; spaces filled with particulated mineralized cortical allograft bone mixed with rhPDGF-BB; Ossix Plus resorbable membrane covered augmentation site.	5 mo	3.9 (17 sites: 1 x max molar, 1 x max premolar, 15 x max anterior)	N/A (123%)
da Costa et al[30]	Randomized clinical trial	10	Group A, allogeneic corticocancellous bone blocks embedded with an autogenous bone marrow aspirate; fixed with titanium screw (n = 5) Group B, allogeneic corticocancellous bone blocks fixed with titanium screw (n = 5)	6 mo	Group A, 4.3 Group B, 4.8	N/A

Width at follow-up (mm)	Bone width gain (mm)	Intra-operative compli-cations	Postoperative complications	Interval between implant place-ment and loading	Follow-up after loading	Implants at follow-up	Implant success (criteria)	Implant survival
7.0 (5–9.75)	3.4 (1–6)	N/A	Soft tissue dehiscence - required partial removal of ePTFE (n = 1) Soft tissue encapsulation (n = 2)	3–4 mo	N/A	N/A	N/A	N/A
N/A	Group A, Mean loss 6% of graft (range, 0%–20%; resorption more pronounced in tuberosity) Group B, no resorption	None	Mucosal dehiscence over graft requiring osteoplasty (n = 3)	6 mo	37 ± 14.6 mo (24–68 mo)	31	96.8% (radiographic examination, no radiolucency; vertical bone loss < 1/5th of implant length [n = 3])	100%
N/A	Mean graft resorption, 0.79 ± 0.6 (0–2); 0.33 for 3–4 mo healing; 1.22 for 5–8 mo healing (P < .001)	None	Fistula above the bone graft, healed spontane-ously after removal of necrotic bone (n = 1) Wound dehiscence in donor sites (n = 4) Sensitivity loss remaining in 2 out of 10 patients 12 mo postop	N/A	20.8 ± 7.7 mo	42	N/A	N/A
N/A	N/A	N/A	None	6 mo	12 mo	91	N/A (All groups, peri-implant hard and soft tissue stable after 12 months; radiographic ex-amination; clinical examination; MBL; PS; BI; PD; MGL)	Group A, 100% Group B, 100% Group C, 93.5% (implant loss, n = 2) All groups, 97.8%
N/A	N/A	N/A	N/A	6 mo	Minimum 1 y	20	N/A (All groups, peri-implant hard and soft tissue stable after 12 months; radiograph-ic examination; clinical examination; MBL; PI; BI; PD)	100%
N/A	N/A	N/A	N/A	Minimum 3 mo	4.1 ± 1.9 y (1.2–8.1 y)	60	100% (success criteria by Smith and Zarb); clinical examina-tion; KM (buccal); mPI; PD	100%
6.9 ± 1.4 (3–9)	3.6 ± 1.5 (0–6)	N/A	None (n = 1, no gain of bone volume)	4 mo	N/A	N/A	N/A	N/A
8.4	4.5 (1.5–9.8)	N/A	None (n = 1, significant resorption at reentry)	4 mo	N/A	N/A	N/A	N/A
Group A, 8.9 Group B, 6.9	Group A, 4.6 ± 1.43 Group B, 2.15 ± 0.47 (*P* = .005)	N/A	N/A	N/A	N/A	40	N/A	N/A

Table 3 *continued* **Results of Studies Using Staged Approach**

Author	Study type	Patients	Techniques	Interval augmentation and implant placement	Width before grafting (mm)	Width after grafting (mm)
Nissan et al[27]	Cohort, retrospective	31	Freeze-dried cancellous block allograft, fixed with bone screws; particulated bone, mineralized freeze-dried bone allograft, or DBBM were used to fill any deficiencies; collagen membranes used.	6 mo	< 3	N/A
Nissan et al[28]	Cohort, retrospective	43	Freeze-dried cancellous block allograft; fixed with bone screws; particulated bone, mineralized freeze-dried bone allograft, or DBBM were used to fill any deficiencies; collagen membranes used.	6 mo	< 3	N/A

MBL: marginal bone level, clinical examination; PI: Plaque Index; BI: Bleeding Index; PD: Probing depth; MGL: marginal gingiva level; KM: keratinized mucosa buccal; mPI: modified Plaque Index.

Two implants were lost during the healing phase in the DBBM group although sites augmented with DBBM particles were left to heal for 6 months before implant placement (compared to 3 months for chin-bone augmented sites). Since the study was terminated after 1 year of implant loading, the long-term success rates remain unknown. Hämmerle and coworkers[21] also used granules or blocks of DBBM for staged ridge augmentation, but waited 9 to 10 months before implant placement. In one out of 12 sites, no gain of bone volume was observed at reentry. The tissue was inflamed and the DBBM granules were encapsulated into connective tissue. Long-term follow-up information regarding implant success and survival rates are not available yet. Both studies[21,29] indicate that a particulate graft may not have the same potential for staged ridge augmentation compared to a block graft, as has been documented previously in other clinical studies.[34–38] This has been attributed mainly to the instability of graft particles due to mucosal pressure or mechanical load (provisional, mastication). Therefore, caution must be exercised when using a particulate graft for staged horizontal ridge augmentation in large bone deficiencies. The quantity of horizontal bone gain in the anterior maxilla documented in this review is similar to the figures reported in previous studies about horizontal ridge augmentation.[34–41] Mean values of bone gain in this systematic review ranged from 2.15 to 5 mm, whereas previous reports not restricted to the anterior maxilla have described gain of bone width between 1.1 to 2.7 mm for particulate grafts[34–38] and 2.9 to 5 mm for block grafts.[8,39–41] In the present systematic review, the actual bone or bone substitute material and surgical technique utilized for horizontal ridge augmentation varied considerably among the studies (Fig 2). All materials led to the gain of bone width: autogenous block grafts with ePTFE-membrane coverage (gain of width, 3.4 mm),[20] DBBM blocks or granules with collagen membrane coverage (gain of width, 3.6 mm[21]), freeze-dried allograft bone block with platelet-rich plasma and recombinant platelet derivative growth factor (rhPDGF-BB) and chemically modified collagen membrane (gain of width, 4.5 mm[22]), allogeneic corticocancellous bone block with (gain of width, 4.6 mm) or without (gain of width, 2.15 mm[30]) autogenous bone marrow aspirate, freeze-dried allograft bone block with particulate bone or allograft, or DBBM with collagen membrane (gain of width, 5 mm[27]). To further complicate the drawing of any conclusions, the interval between ridge augmentation and reentry varied considerably among the studies (5 to 13 months). Two other studies did not report bone gain but rather the amount of graft resorption.[23,24] An interesting phenomenon was documented by Dörtbudak et al[24] when chin bone blocks for horizontal ridge augmentation were used. Significantly less surface resorption of grafts in sites reentered 3 to 4 months after augmentation (0.33 mm) were found compared to sites reentered 5 to 8 months after augmentation (1.22 mm). Whether this difference was clinically relevant is unknown since the authors did not mention the initial width of the bone blocks. The benefit of barrier membranes to avoid surface resorption of autogenous bone blocks remains unclear. Although several clinical studies have documented a positive effect,[8,20,39] a systematic review on that topic found that the available evidence is too weak to support a protective effect of a barrier membrane.[13]

With regard to complications in staged horizontal bone augmentation, such information has been divided

Width at follow-up (mm)	Bone width gain (mm)	Intra-operative compli-cations	Postoperative complications	Interval between implant place-ment and loading	Follow-up after loading	Implants at follow-up	Implant success (criteria)	Implant survival
N/A	5 ± 0.5 (4–6)	N/A	Soft tissue break-down and graft expo-sure with complete failures of two blocks (n = 13 [28%])	6 mo	34 ± 16 mo (6–59 mo)	63 (n = 19 with im-mediate loading)	N/A	100% implant survival in delayed loading; 98% for immediate nonfunctional loading. (Not all implants had minimum 1 y loading.)
N/A	N/A	N/A	Soft tissue dehiscen-ces in 16 sites in 27 block allografts with vertical alone or in combination with hori-zontal augmentation	3 mo	48 ± 22 mo (14–82 mo)	83	N/A	98.8%

into intra- and postoperative complications. Studies included in this systematic review either did not mention if intraoperative complications had occurred, or they reported that no such intraoperative complications were observed. In contrast, postoperative complications were reported in five studies.[20,23,24,27,28] All of these studies reported soft tissue complications relating to block graft augmentation, such as mucosal dehiscences, soft tissue breakdown, or sinus tract formation (fistula). As reported by Nissan et al,[27] soft tissue dehiscence may lead to complete failure of block grafts and must be taken seriously. Interestingly, cohorts of both studies by Nissan et al[27,28] had relatively large frequencies of soft tissue complications, although augmented sites were covered with collagen membranes. The authors used different types of collagen membranes, but they did not specify if mucosal dehiscences occurred more frequently in one membrane versus another. Furthermore, it cannot be ruled out that a vertical component of horizontal ridge augmentation caused the soft tissue breakdown with subsequent graft exposure. In those studies using autogenous bone blocks, only one study provided data about donor site morbidity.[24] The authors describe two patients with persistent sensitivity loss of anterior mandibular teeth 12 months postsurgically. Many studies have reported sensitivity changes of perioral soft tissues or of adjacent teeth, particularly following bone block harvesting in the symphysis.[42–45] As a consequence, grafts and bone substitutes other than the autogenous type of block grafts are also used increasingly for staged horizontal ridge augmentation, as shown with this systematic review. The last four studies included in this review all utilized nonautogenous grafts for reconstruction of deficient alveolar processes.

CONCLUSIONS

The number of articles meeting the outcome parameters in simultaneous versus staged horizontal augmentation procedures in the anterior maxilla is limited. Most of the excluded publications describing augmentation procedures in the anterior maxilla are case reports with a high risk of bias. Within the 13 articles meeting the inclusion criteria, only one randomized clinical trial was found. Therefore no conclusions can be drawn for the best performing material for augmentation in the anterior maxilla. In summary, the authors found that bone augmentation and implant placement is associated with high implant success and survival rates in both treatment modalities with different bone substitutes.

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REFERENCES

1. Dong JK, Jin TH, Cho HW, Oh SC. The esthetics of the smile: A review of some recent studies. Int J Prosthodont 1999;12:9–19.
2. Henson ST, Lindauer SJ, Gardner WG, Shroff B, Tufekci E, Best AM. Influence of dental esthetics on social perceptions of adolescents judged by peers. Am J Orthod Dentofacial Orthop 2011;140:389–395.
3. Wang HL, Al-Shammari K. HVC ridge deficiency classification: A therapeutically oriented classification. Int J Periodontics Restorative Dent 2002;22:335–343.
4. Misch CE, Judy KW. Classification of partially edentulous arches for implant dentistry. Int J Oral Implantol 1987;4:7–13.

5. Cawood JI, Howell RA. A classification of the edentulous jaws. Int J Oral Maxillofac Surg 1988;17:232–236.
6. Tinti C, Parma-Benfenati S. Clinical classification of bone defects concerning the placement of dental implants. Int J Periodontics Restorative Dent 2003;23:147–155.
7. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol 2007;78:377–396.
8. von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: A clinical study with 42 patients. Clin Oral Implants Res 2006;17:359–366.
9. Buser D, Bornstein MM, Weber HP, Grutter L, Schmid B, Belser UC. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in the esthetic zone: A cross-sectional, retrospective study in 45 subjects with a 2- to 4-year follow-up. J Periodontol 2008;79:1773–1781.
10. Braut V, Bornstein MM, Belser U, Buser D. Thickness of the anterior maxillary facial bone wall-a retrospective radiographic study using cone beam computed tomography. Int J Periodontics Restorative Dent 2011;31:125–131.
11. Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Implants Res 2006;17(suppl 2):136–159.
12. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 2007;22(suppl):49–70.
13. Gielkens PF, Bos RR, Raghoebar GM, Stegenga B. Is there evidence that barrier membranes prevent bone resorption in autologous bone grafts during the healing period? A systematic review. Int J Oral Maxillofac Implants 2007;22:390–398.
14. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: A systematic review. J Clin Periodontol 2008;35:203–215.
15. Chiapasco M, Zaniboni M. Clinical outcomes of GBR procedures to correct peri-implant dehiscences and fenestrations: A systematic review. Clin Oral Implants Res 2009;20(suppl 4):113–123.
16. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: Clinical results with different bone grafts and bone-substitute materials. Int J Oral Maxillofac Implants 2009;24(suppl):218–236.
17. Waasdorp J, Reynolds MA. Allogeneic bone onlay grafts for alveolar ridge augmentation: A systematic review. Int J Oral Maxillofac Implants 2010;25:525–531.
18. Buser D, Wittneben J, Bornstein MM, Grutter L, Chappuis V, Belser UC. Stability of contour augmentation and esthetic outcomes of implant-supported single crowns in the esthetic zone: 3-year results of a prospective study with early implant placement postextraction. J Periodontol 2011;82:342–349.
19. Schneider D, Grunder U, Ender A, Hämmerle CH, Jung RE. Volume gain and stability of peri-implant tissue following bone and soft tissue augmentation: 1-year results from a prospective cohort study. Clin Oral Implants Res 2011;22:28–37.
20. Buser D, Dula K, Lang NP, Nyman S. Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. 5-year results of a prospective study with 12 implants. Clin Oral Implants Res 1996;7:175–183.
21. Hämmerle CH, Jung RE, Yaman D, Lang NP. Ridge augmentation by applying bioresorbable membranes and deproteinized bovine bone mineral: A report of twelve consecutive cases. Clin Oral Implants Res 2008;19:19–25.
22. Wallace S, Gellin R. Clinical evaluation of freeze-dried cancellous block allografts for ridge augmentation and implant placement in the maxilla. Implant Dent 2010;19:272–279.
23. Raghoebar GM, Batenburg RH, Vissink A, Reintsema H. Augmentation of localized defects of the anterior maxillary ridge with autogenous bone before insertion of implants. J Oral Maxillofac Surg 1996;54:1180–1185; discussion 1185–1186.
24. Dörtbudak O, Haas R, Bernhart T, Mailath-Pokorny G. Inlay autograft of intra-membranous bone for lateral alveolar ridge augmentation: A new surgical technique. J Oral Rehabil 2002;29:835–841.
25. Tymstra N, Meijer HJ, Stellingsma K, Raghoebar GM, Vissink A. Treatment outcome and patient satisfaction with two adjacent implant-supported restorations in the esthetic zone. Int J Periodontics Restorative Dent 2010;30:307–316.
26. Hof M, Pommer B, Strbac GD, Suto D, Watzek G, Zechner W. Esthetic evaluation of single-tooth implants in the anterior maxilla following autologous bone augmentation. Clin Oral Implants Res 2011 Dec 8 [epub ahead of print]
27. Nissan J, Mardinger O, Calderon S, Romanos GE, Chaushu G. Cancellous bone block allografts for the augmentation of the anterior atrophic maxilla. Clin Implant Dent Relat Res 2011;13:104–111.
28. Nissan J, Marilena V, Gross O, Mardinger O, Chaushu G. Histomorphometric analysis following augmentation of the anterior atrophic maxilla with cancellous bone block allograft. Int J Oral Maxillofac Implants 2012;27:84–89.
29. Meijndert L, Raghoebar GM, Meijer HJ, Vissink A. Clinical and radiographic characteristics of single-tooth replacements preceded by local ridge augmentation: A prospective randomized clinical trial. Clin Oral Implants Res 2008;19:1295–1303.
30. da Costa CE, Pelegrine AA, Fagundes DJ, Simoes Mde J, Taha MO. Use of corticocancellous allogeneic bone blocks impregnated with bone marrow aspirate: A clinical, tomographic, and histomorphometric study. Gen Dent 2011;59:e200–e205.
31. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: Stage 1 placement through stage 2 uncovering. Ann Periodontol 2000;5:119–128.
32. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent 2005; 25:113–119.
33. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: Clinical outcomes and esthetic results. Clin Oral Implants Res 2007;18:552–562.
34. ten Bruggenkate CM, Kraaijenhagen HA, van der Kwast WA, Krekeler G, Oosterbeek HS. Autogenous maxillary bone grafts in conjunction with placement of ITI endosseous implants. A preliminary report. Int J Oral Maxillofac Surg 1992;21:81–84.
35. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. Clin Oral Implants Res 1999;10:278–288.
36. Simon BI, Von Hagen S, Deasy MJ, Faldu M, Resnansky D. Changes in alveolar bone height and width following ridge augmentation using bone graft and membranes. J Periodontol 2000;71:1774–1791.
37. Knapp CI, Feuille F, Cochran DL, Mellonig JT. Clinical and histologic evaluation of bone-replacement grafts in the treatment of localized alveolar ridge defects. Part 2: Bioactive glass particulate. Int J Periodontics Restorative Dent 2003;23:129–137.
38. Meijndert L, Raghoebar GM, Schupbach P, Meijer HJ, Vissink A. Bone quality at the implant site after reconstruction of a local defect of the maxillary anterior ridge with chin bone or deproteinized cancellous bovine bone. Int J Oral Maxillofac Surg 2005;34:877–884.
39. Antoun H, Sitbon JM, Martinez H, Missika P. A prospective randomized study comparing two techniques of bone augmentation: Onlay graft alone or associated with a membrane. Clin Oral Implants Res 2001;12:632–639.
40. Cordaro L, Amade DS, Cordaro M. Clinical results of alveolar ridge augmentation with mandibular block bone grafts in partially edentulous patients prior to implant placement. Clin Oral Implants Res 2002;13:103–111.
41. Maiorana C, Beretta M, Salina S, Santoro F. Reduction of autogenous bone graft resorption by means of bio-oss coverage: A prospective study. Int J Periodontics Restorative Dent 2005;25:19–25.
42. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: Comparison of donor site morbidity and complications. Clin Implant Dent Relat Res 2003;5:154–160.
43. von Arx T, Chappuis V, Winzap-Kalin C, Bornstein MM. Laser Doppler flowmetry for assessment of anterior mandibular teeth in conjunction with bone harvesting in the symphysis: A clinical pilot study. Int J Oral Maxillofac Implants 2007;22:383–389.
44. von Arx T, Hafliger J, Chappuis V. Neurosensory disturbances following bone harvesting in the symphysis: A prospective clinical study. Clin Oral Implants Res 2005;16:432–439.
45. Raghoebar GM, Meijndert L, Kalk WW, Vissink A. Morbidity of mandibular bone harvesting: A comparative study. Int J Oral Maxillofac Implants 2007;22:359–365.