Emeka Nkenke
Florian Stelzle

Clinical outcomes of sinus floor augmentation for implant placement using autogenous bone or bone substitutes: a systematic review

Authors' affiliations:
Emeka Nkenke, Florian Stelzle, Department of Oral and Maxillofacial Surgery, University Hospital of Erlangen, Erlangen, Germany

Correspondence to:
Prof. Dr. Dr. *Emeka Nkenke*
Department of Oral and Maxillofacial Surgery
University Hospital of Erlangen
Glueckstr 11
91054 Erlangen
Germany
Tel.: +49 9131 8533653
Fax: +49 9131 8534219
e-mail: emeka.nkenke@uk-erlangen.de

Conflicts of interest:
The authors declare no conflicts of interest.

Key words: autogenous bone, bone substitute, complication, implant survival, sinus floor augmentation

Abstract

Background: To date, there are still no clear cut guidelines for the use of autogenous bone or bone substitutes.

Aim: The aim of the present review was to analyze the current literature in order to determine whether there are advantages of using autogenous bone (AB) over bone substitutes (BS) in sinus floor augmentation. The focused question was: is AB superior to BS for sinus floor augmentation in partially dentate or edentulous patients in terms of implant survival, patient morbidity, sinusitis, graft loss, costs, and risk of disease transmission?

Materials and methods: The analysis was limited to titanium implants with modified surfaces placed in sites with 6 mm of residual bone height and a lateral wall approach to the sinus. A literature search was performed for human studies focusing on sinus floor augmentation.

Results: Twenty-one articles were included in the review. The highest level of evidence consisted of prospective cohort studies. A descriptive analysis of the constructed evidence tables indicated that the type of graft did not seem to be associated with the success of the procedure, its complications, or implant survival. Length of healing period, simultaneous implant placement or a staged approach or the height of the residual alveolar crest, sinusitis or graft loss did not modify the lack of effect of graft material on the outcomes. Three studies documented that there was donor site morbidity present after the harvest of AB. When iliac crest bone was harvested this sometimes required hospitalization and surgery under general anesthesia. Moreover, bone harvest extended the operating time. The assessment of disease transmission by BS was not a topic of any of the included articles.

Discussion and Conclusion: The retrieved evidence provides a low level of support for selection of AB or a bone substitute. Clear reasons could not be identified that should prompt the clinician to prefer AB or BS.

Sinus floor augmentation is a technique based on the elevation of the sinus membrane from the floor of the maxillary sinus. Various graft materials have been used to fill the newly formed space. Autogenous bone (AB), allografts, xenografts, alloplastic materials, and mixtures of various materials have been proposed for this purpose (Wheeler 1997).

AB is very popular for sinus floor augmentation, because it possesses osteoconductive, osteoinductive, and osteogenic properties (Galindo-Moreno et al. 2008). Unfortunately, the harvest of AB requires donor site surgery and potentially increases patient morbidity (Nkenke et al. 2001, 2002, 2004). In this context, it is important to note that maxillary sinus floor augmentation is an elective procedure. In such kind of surgery, it should always be a priority to reduce patient morbidity to a minimum.

Date:
Accepted 20 May 2009

To cite this article:
Nkenke E, Stelzle F. Clinical outcomes of sinus floor augmentation for implant placement using autogenous bone or bone substitutes: a systematic review.
Clin. Oral Impl. Res. **20** (Suppl. 4), 2009; 124–133.
doi: 10.1111/j.1600-0501.2009.01776.x

It has been clearly stated that donor site morbidity cannot be ignored when AB is used for maxillary sinus floor augmentation (Kübler et al. 1999; Raghoebar et al. 1999).

Harvesting AB from intraoral sites can be associated with a number of problems like devitalization of anterior mandibular teeth by involvement of tooth apices, changes in facial esthetics, possible damage to mental and lower dental nerves, and increased risk of mandibular ramus fracture when intraoral donor sites are chosen (Galindo-Moreno et al. 2007). Bone harvest from extraoral sites may cause hemorrhage, instability of the sacro-iliac joint, hernia through the donor site, adynamic ileus, or gait disturbances (Kalk et al. 1996). As a consequence, the use of AB for sinus floor augmentation has been questioned (Tadjoedin et al. 2002).

Therefore, it was the aim of the present review to determine whether there are advantages in using AB over bone substitutes (BS) for sinus floor augmentation. The question focused on was: is AB superior to BS for sinus floor augmentation in partially dentate or edentulous patients in terms of implant survival, patient morbidity, sinusitis, graft loss, costs, and risk of disease transmission?

Materials and methods

Search strategy

A systematic search strategy was used. In the initial phase of the review, a computerized literature search for human studies was performed (Medline and Embase databases, 1 January 1966–31 December 2008). There was no language restriction.

In addition, a hand search was carried out in *Annals of Periodontology*, *British Journal of Oral and Maxillofacial Surgery*, *Clinical Implant Dentistry & Related Research*, *Clinical Oral Implants Research*, *Dental Clinics of North America*, *Implant Dentistry*, *The International Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal of Clinical Periodontology*, *Journal of Cranio-Maxillofacial Surgery*, *Journal of Oral Implantology*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*, *Journal of the American Dental Association*, *Mund-, Kiefer- und Gesichtschirurgie*, *Oral and Maxillofacial Surgery*, *Oral Surgery Oral Medicine Oral Pathology*, *Periodontology 2000*, *Scandinavian Journal of Plastic and Reconstructive Surgery*, and *The International Journal of Oral & Maxillofacial Implants*.

Moreover, the Cochrane Controlled Trials Register and The Cochrane Health Group Specialized Register were checked for publications on sinus floor augmentation.

The full text of reviews was obtained from reviews on sinus floor augmentation published between 1 January 1998 and 31 December 2008. Additional publications were identified from the reference lists of the retrieved articles.

Search terms

Keywords were 'sinus augmentation' OR 'sinus floor augmentation' OR 'sinus floor elevation' OR 'sinus grafting' OR 'sinus lift'. The search was limited to 'human trial' (MeSH term, clinical studies). Additionally, the MeSH terms 'clinical trial', 'comparative study', 'controlled clinical trial', 'randomized controlled trial', 'meta-analysis', and 'review' were used.

Inclusion criteria

The inclusion criteria for study selection were:

(i) clinical studies,
(ii) lateral window approach to the sinus,
(iii) elevation of sinus mucosa,
(iv) use of an augmentation material,
(v) use of root-form or cylindrical titanium implants with modified surfaces,
(vi) studies with a follow-up interval of at least 12 months after functional loading of the implants placed in the region of the sinus floor augmentation,
(vii) average residual height of pristine bone in the region of sinus floor augmentation of a maximum of 6 mm,
(viii) defined survival or success criteria for the implants placed in the region of the sinus floor augmentation,
(xi) documentation of the implant survival rate after a defined period of time, and
(x) a sample size of at least 10 patients.

Exclusion criteria

Publications dealing with *in vitro* studies or preclinical (animal) studies were excluded. Human studies not meeting all inclusion criteria were also excluded from the review:

In addition, studies were excluded if

(i) additional augmentation procedures were carried out besides sinus floor augmentation,
(ii) survival rates or success rates could not be distinguished for rough- and smooth-surfaced implants,
(iii) they reported on the same patient cohort, and
(iv) personal communication was included in the paper.

Selection of studies

Titles derived from this broad search were independently screened by the two authors based on the inclusion criteria. Disagreements were resolved by discussion. Following this, abstracts of all titles agreed on by both authors were obtained and screened for meeting the inclusion criteria. If no abstract was available in the database, the abstract of the printed article was used. The selected articles were then obtained in full text. If the title and abstract did not provide sufficient information regarding the inclusion criteria, the full report was obtained as well. Again, disagreements were resolved by discussion.

Finally, the selection based on inclusion and exclusion criteria was made for the full-text articles. For this purpose, Material and Methods and Results of these studies were screened. This step was again carried out independently by the two authors. Disagreements were resolved by discussion (Fig. 1).

Data extraction

Two reviewers independently extracted the data using data extraction tables. Any disagreements were resolved by double-checking the original data and by discussion. From the selected papers, data were extracted on author(s), year of publication, study design, total number of patients, inclusion and exclusion criteria, follow-up period, patients lost to follow-up, healing period, simultaneous implant placement or staged approach, height of residual alveolar crest, sinus mucosa perforation, operating time, sinusitis, graft loss, patient morbidity, disease transmission, and costs.

All abbreviations used in the text are given in Table 1.

Results

Study characteristics

By the electronic literature search, a total of 1028 titles were identified. Twenty-one original articles fulfilled the inclusion criteria (Fig. 1). The studies with the highest level of evidence were prospective cohort studies (Table 2).

Exclusion of studies

The reasons for excluding studies after the full text was obtained were a sample size of <10 patients (15 articles), not reporting on sinus floor augmentation (three articles), additional augmentation procedures (two articles), surgical technique other than a lateral approach (36 articles), no implant survival data (33 articles), no information on the residual height of the alveolar crest before surgery (25 articles), a mean bone level >6 mm before surgery (nine articles), <1 year of follow-up (seven articles), <1 year of functional loading of implants (four articles), multiple publications on the same patient cohorts (12 articles), titanium implants without modified surfaces or surfaces not specified (24 articles), and implant survival rates not distinguishable for implants with modified surfaces and implants with other surfaces (three articles) (Fig. 1).

Included studies

Twenty-one articles were selected for inclusion in a narrative review. They are presented in Tables 2–8. Fourteen studies reported inclusion and exclusion criteria for their patients. Most often, patients with a history of sinusitis, immune system disorders, and uncontrolled systemic diseases were excluded. While most of the studies excluded smokers, they were explicitly included in two studies (Table 3). The exclusion criteria did not differ for augmentation procedures with AB or BS.

Patients lost to follow-up were documented in 12 studies (Table 4).

The approach to the sinus through the lateral antral wall was either performed by a trap door technique (13 studies) or by the preparation of an access hole by removal of the buccal bone plate (six studies) (Table 4). In three studies, the approach was not reported in detail.

In 10 studies, groups with sinus floor augmentation and simultaneous implant placement and groups with a staged approach were included. In these studies, the decision on the use of one or the other technique was based on the height of the residual crestal bone beyond the sinus. In eight studies, a staged approach was used exclusively, while in four studies only sinus floor augmentation with simultaneous implant placement was performed (Table 5). No differences were detectable for implant survival rates for the different graft materials that were associated by simultaneous or staged implant placement.

A wide variety of sources for AB were used. AB from the chin, the mandibular ramus, the calvarium, and the iliac crest was included. In 16 studies, AB was com-

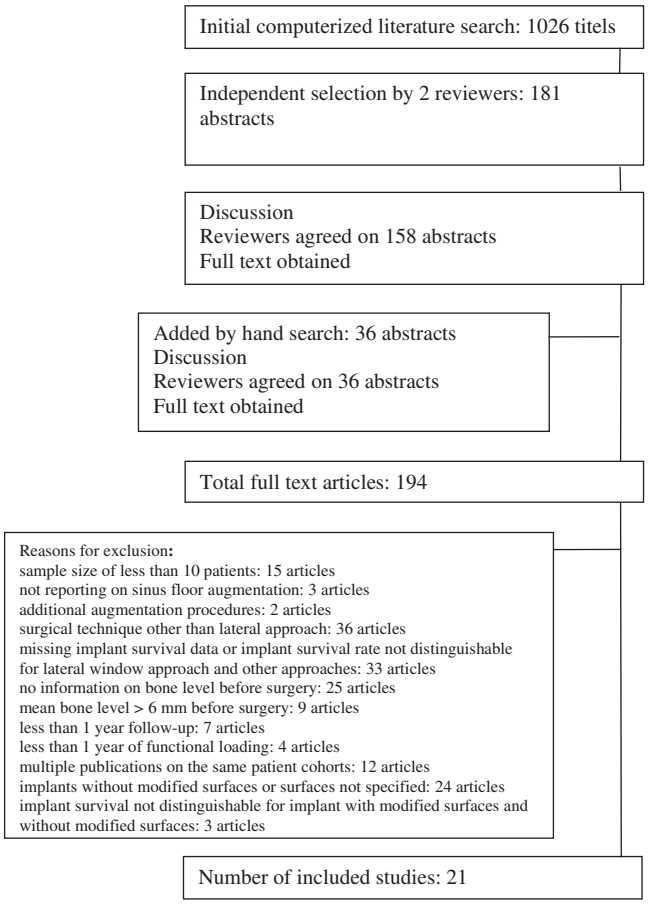

Fig. 1. Search strategy: sinus floor augmentation by a lateral approach.

Table 1. **Abbreviations used in the text**

Abbreviation	Full text
AB	Autogenous bone
β-TCP	β-tri-calcium phosphate
BS	Bone substitutes
BSE	Bovine spongiform encephalopathy
CI	Confidence interval
CJD	Creutzfeldt–Jakob disease
DBBM	Deproteinized bovine bone mineral
DFDBA	Demineralized freeze-dried bone allograft
HA	Hydroxyapatite
ICB	Irradiated cancellous bone
MBCP	Macroporous biphasic calcium phosphate
PCCS	Prospective comparative case series
PCS	Prospective case series
PRP	Platelet rich plasma
RCCS	Retrospective comparative case series
RCS	Retrospective case series
VCJD	New variant Creutzfeldt–Jakob disease

Table 2. **Study design and basic patient data**

Authors	Design of study	Patients			
		Number of patients (*n*)	Age range (years)	Mean age (years)	Residual bone height (mm)
Kim et al. (2009)	RCCS	28	NS	NS	4.5
Kahnberg & Vannas-Löfqvist (2008)	PCS	36	NS	60	5–6
Lee et al. (2008)	PCCS	52	30–73	50	<6
Galindo-Moreno et al. (2007)	PCS	70	NS	NS	≥5/<5
Krennmair et al. (2007)	RCS	37	37–66	NS	3.5
Marchetti et al. (2007)	PCS	30	23–67	48.8	5.3/2.5
Karabuda et al. (2006)	PCS	91	29–74	46	≥5/<5
Lindenmüller & Lambrecht (2006)	RCCS	80	18–82	57	4.5/2.4
Peleg et al. (2006)	PCS	731	42–81	53	1–5
Hallman & Nordin (2004)	RCS	50	23–82	61	<5
Iturriaga & Ruiz (2004)	RCS	58	NS	NS	<5
Mazor et al. (2004)	PCS	105	25–69	51	<5
Peleg et al. (2004)	PCCS	156	NS	NS	≤5
Engelke et al. (2003)	PCS	83	27–86	55.6	5.8
Stricker et al. (2003)	PCS	41	38–73	55	≥5/<5
Valentini & Abensur (2003)	RCCS	59	NS	NS	≥5/<5
van den Bergh et al. (2000)	PCS	24	32–65	50	<4
Kaptein et al. (1998)	RCS	77	36–76	51	<5
van den Bergh et al. (1996)	PCS	42	22–64	44	<4
Watzek et al. (1998)	RCCS	20	43–76	53.2	2.1
Zinner & Small (1996)	PCS	50	30–71	NS	<5

NS, not specified; PCCS, prospective comparative case series; PCS, prospective case series; RCCS, retrospective comparative case series; RCS, retrospective case series.

bined with a bone substitute. In seven studies patient groups were included, where sinus floor augmentation was carried out with BS alone. The combination of autogenous bone with fibrin glue or PRP was also reported (Table 6). The use of membranes for the coverage of the lateral window and the prescription of antibiotics are outlined in Table 3. The use of membranes did not seem to influence implant survival in dependence of the graft material used.

Sinus membrane perforation was the most frequently reported complication. It ranged from 0% to 58% of the cases. Acute sinusitis was found during the postoperative course in a range of 0–22%. Partial graft loss was found in 0–25% of the cases. Total graft loss occurred in up to 2.6% of the cases. Neither sinusitis, partial graft loss, or total graft loss could be attributed to a specific graft material (Table 7).

Donor site morbidity was specified in three studies (Watzek et al. 1998; Iturriaga & Ruiz 2004; Marchetti et al. 2007). Harvesting of bone from the iliac crest led to donor site morbidity within the first two postoperative weeks (Marchetti et al. 2007). Donor site infections were found after harvest of mandibular ramus grafts. Hematomas, penetration into the cranial cavity, and minimal patches of alopecia were found after harvest of calvarial bone (Iturriaga & Ruiz 2004). The volume of harvested AB was assessed in only one study (Peleg et al. 2004).

Healing periods after simultaneous implant placement ranged from 2 to 10 months. In staged approaches, healing periods for the graft material from 3 to 13 months were chosen. After implant placement additional healing periods of up to 10 months were reported (Table 5). The length of the healing periods did not seem to influence implant survival in dependence of the graft material used.

The implant survival rate was not influenced by the use of AB alone or BS for sinus floor augmentation. When combinations of different graft materials were used, the implant survival rate for >12 months of follow-up under functional loading exceeded 90% for most of the studies (Table 8). Only in one study was the influence of smoking on implant survival assessed (Lindenmüller & Lambrecht 2006). In smokers, the implant survival rate was 85.4% compared with 93.3% in non-smokers after 2 years. However, the survival data were not specified for the different graft materials. None of the studies examined whether systemic diseases or other risk factors had an influence on implant survival in dependence of the different graft materials used.

From the studies included in the review no clear trend could be derived concerning the aspect whether sinus floor augmentation and simultaneous implant placement or a staged approach should be preferred as far as implant survival is concerned (Table 8).

The resorption of the graft material over time was documented in some of the studies (Hallman & Nordin 2004; Kim et al. 2009). Graft resorption did not seem to influence implant survival in dependence of the graft material used.

None of the studies that used allogenic or xenogenic material was designed to report on the transmission of infectious diseases. Cases of disease transmission were not documented in any of the studies.

The aspect of cost was not explicitly treated in any of the studies. However, it was reported that bone harvesting led to an extension of operating time of up to 15 min, when intraoral donor sites were chosen (Peleg et al. 2004). Moreover, it was mentioned that surgery was carried out under general anesthesia when iliac crest bone was harvested and that patients were hospitalized up to 5 days after this procedure (Marchetti et al. 2007).

Discussion

Sinus floor augmentation is one of the most reliable procedures in preprosthetic surgery. A number of systematic reviews and meta-analyses have been performed on this topic (Table 9). These reviews have shown that titanium implants without modified surfaces performed significantly worse than implants with modified surfaces when placed following sinus floor augmentation. Therefore, implants without modified surfaces were excluded from the present review. Based on this major change compared with the previous reviews, the aim to determine whether there are advantages in using AB compared with BS for sinus floor augmentation. The question focused on was: is AB superior to BS for sinus floor augmentation in partially dentate or edentulous patients in terms of implant survival, patient morbidity,

Table 3. **Exclusion criteria**

Authors	Exclusion criteria							
	Smokers	Systemic disease	Immune deficiency	Diabetes mellitus	Sinus pathology	Radio-/ chemotherapy	Periodontitis	Others
Kim et al. (2009)	NS	NS	NS	NS	NS	NS	NS	NS
Kahnberg & Vannas-Löfqvist (2008)	EX	EX	NS	NS	NS	NS	NS	NS
Lee et al. (2008)	NS	NS	NS	NS	EX: acute sinusitis	NS	NS	NS
Galindo-Moreno et al. (2007)	Included	EX: uncontrolled systemic disease	NS	NS	EX: history of chronic sinusitis	NS	NS	EX: allergies with respiratory component
Krennmair et al. (2007)	NS	NS	NS	NS	NS	NS	NS	NS
Marchetti et al. (2007)	Included	NS	EX	EX	NS	EX	NS	EX: history of drug abuse
Karabuda et al. (2006)	EX	NS	EX	EX: uncontrolled diabetes mellitus	EX: history of chronic sinusitis	EX: ongoing radio- and chemotherapy	NS	NS
Lindenmüller & Lambrecht (2006)	NS	NS	NS	EX: uncontrolled diabetes mellitus	EX: sinusitis/ previous sinus surgery	EX: radiotherapy	NS	EX: cysts/tumors in head and neck area
Peleg et al. (2006)	NS	NS	EX	NS	EX	EX: previous radiotherapy	NS	NS
Hallman & Nordin (2004)	NS	EX: severe systemic disease	NS	EX: uncontrolled diabetes mellitus	NS	EX: history of radiotherapy in head and neck area	EX	NS
Iturriaga & Ruiz (2004)	NS	NS	NS	NS	NS	NS	NS	NS
Mazor et al. (2004)	NS	NS	NS	NS	NS	NS	NS	NS
Peleg et al. (2004)	NS	NS	NS	NS	NS	NS	NS	NS
Engelke et al. (2003)	NS	EX	NS	NS	EX: sinusitis	NS	EX: untreated periodontitis	NS
Stricker et al. (2003)	NS	NS	EX	EX: uncontrolled diabetes mellitus	NS	EX: ongoing radio- and chemotherapy	NS	EX: history of drug abuse
Valentini & Abensur (2003)	EX	NS	NS	NS	NS	NS	NS	NS
van den Bergh et al. (2000)	NS	EX	EX	NS	EX	NS	NS	EX: alcoholism, history of endocarditis heart valve prosthesis metallic joint prosthesis
Kaptein et al. (1998)	NS	NS	NS	NS	NS	NS	NS	NS
van den Bergh et al. (1996)	NS	EX	EX	NS	EX	NS	NS	EX: alcoholism, history of endocarditis heart valve prosthesis metallic joint prosthesis
Watzek et al. (1998)	NS	NS	NS	NS	EX	NS	NS	NS
Zinner & Small (1996)	NS	NS	NS	NS	NS	NS	NS	NS

NS, not specified; EX, excluded.

sinusitis, graft loss, costs, and risk of disease transmission?

A major concern with the use of AB is donor site morbidity (Nkenke et al. 2001, 2002, 2004). In the present review, three studies were included that also showed that donor site morbidity cannot be ignored (Watzek et al. 1998; Iturriaga & Ruiz 2004; Marchetti et al. 2007). It seems that donor site morbidity can be a major reason to question the use of AB.

On the other hand, allografts and xenografts used as alternatives to autografts have a potential for disease transmission (Cordioli et al. 2001). Infectious particles (prions) cause Creutzfeldt–Jakob disease (CJD) in humans and bovine spongiform encephalopathy (BSE) in cattle. Therefore, the use of xenogenic material for medical products and devices poses the question: to what degree such material can be consid-

Table 4. **Characteristics of surgical procedures**

Authors	Characteristics of surgical procedures					
	Simultaneous implant placement/staged approach	Antibiotics	Surgical approach	Membrane coverage of lateral window	Mean follow-up (month)	Lost to follow-up (%)
Kim et al. (2009)	Simultaneous/staged	NS	Access hole	Resorbable	12	0
Kahnberg & Vannas-Löfqvist (2008)	Staged	NS	Trap door	No	34	0
Lee et al. (2008)	Simultaneous/staged	NS	Access hole	Resorbable	12	0
Galindo-Moreno et al. (2007)	Simultaneous/staged	Pre/post	Access hole	Resorbable	24	NS
Krennmair et al. (2007)	Staged	NS	Access hole	Resorbable	44	0
Marchetti et al. (2007)	Simultaneous/staged	Pre/post	Trap door	No	60	NS
Karabuda et al. (2006)	Simultaneous/staged	Pre/post	Trap door	Resorbable	36	7.7
Lindenmüller & Lambrecht (2006)	Simultaneous/staged	Post	NS	No	24	1.5
Peleg et al. (2006)	Simultaneous	Pre/post	Trap door	Resorbable	108	1.8
Hallman & Nordin (2004)	Staged	Pre/post	NS	No	19	0
Iturriaga & Ruiz (2004)	Staged	NS	Trap door	No	12	NS
Mazor et al. (2004)	Simultaneous	Pre/post	Access hole	Resorbable	22	NS
Peleg et al. (2004)	Staged	Pre/post	Ns	Resorbable	16	NS
Engelke et al. (2003)	Simultaneous/staged	Post	Access hole	No	12	NS
Stricker et al. (2003)	Simultaneous/staged	No	Trap door	No	27.4	0
Valentini & Abensur (2003)	Simultaneous/staged	Pre/post	Trap door	No	73.2	1.7
van den Bergh et al. (2000)	Staged	Pre/post	Trap door	No	12–72*	0
Kaptein et al. (1998)	Staged	Pre/post	Trap door	No	55	NS
van den Bergh et al. (1996)	Staged	Pre/post	Trap door	No	12–72*	0
Watzek et al. (1998)	Staged	Pre/post	Trap door	No	54	NS
Zinner & Small (1996)	Simultaneous	Pre/post	Trap door	Resorbable	60	NS

*Min/max; no mean value given.
NS, not specified.

Table 5. **Healing periods**

Authors	Healing periods		
	Simultaneous implant placement	Staged approach	
	Implant placement – stage 2 surgery (months)	Bone grafting – implant placement (months)	Implant placement – stage 2 surgery (months)
Kim et al. (2009)	NS	4–7	NS
Kahnberg & Vannas-Löfqvist (2008)	–	4–5	6
Lee et al. (2008)	NS	3–13	NS
Galindo-Moreno et al. (2007)	NS	6–8	NS
Krennmair et al. (2007)	–	6–9	NS
Marchetti et al. (2007)	5	5	5
Karabuda et al. (2006)	NS	6	NS
Lindenmüller & Lambrecht (2006)	7.7 (mean)	10.3 (mean)	9.2 (mean)
Peleg et al. (2006)	6–9	–	–
Hallman & Nordin (2004)	–	6–11 (mean)	0.3–10
Iturriaga & Ruiz (2004)	–	3–11	5–9
Mazor et al. (2004)	6	–	–
Peleg et al. (2004)	4–8	–	–
Engelke et al. (2003)	NS	6–12	NS
Stricker et al. (2003)	4.6 (mean)	4.9 (mean)	3.9 (mean)
Valentini & Abensur (2003)	9	6	6
van den Bergh et al. (2000)	–	6	4
Kaptein et al. (1998)	–	3.4 (mean)	4 (mean)
van den Bergh et al. (1996)	–	4	4
Watzek et al. (1998)	–	3–8 (AB) 6 (BS)	6
Zinner & Small (1996)	9	–	–

AB, autogenous bone; BS, bone substitute; NS, not specified.

ered free of prions and what are the risks of transmission of the disease to humans. Cases have been reported of iatrogenic transmission of CJD from humans to humans through the use of human-derived medicinal products (Brown et al. 1992). While the appearance of the new variant CJD (vCJD) appears to be caused through consumption of infectious bovine food, none of the vCJD patients had a history of surgery and the use of xenografts (Will et al. 1996). Allografts also pose the risk of transmission of other infectious diseases, such as acquired immunodeficiency syndrome. However, it has been stated that adequate material processing including freezing, demineralization, and lyophilization can decrease the risk of infection transmission to minimum (Gomes et al. 2008). Consequently, no case of transmission of one of the mentioned infectious diseases was described in the studies included in the present review. Although, none of the studies was designed to highlight the problem of disease transmission, it seems that the risk for transmission of these diseases by BS is minimal.

It is well known that sinus membrane perforation is a common technical problem

Table 6. **Grafting materials and implant types**

Authors	Grafting material	Implants
Kim et al. (2009)	AB + DBBM/AB + Allograft + DBBM	Osstem Implant
Kahnberg & Vannas-Löfqvist (2008)	AB (iliac/mand)/AB + DBBM	Tioblast ST Implants
Lee et al. (2008)	MBCP/MBCP + ICB/MBCP + AB	TiUnite, ITI
Galindo-Moreno et al. (2007)	AB + DBBM + PRP	Astra, Microdent
Krennmair et al. (2007)	AB + DBBM	Frialit 2, Camlog
Marchetti et al. (2007)	70% AB + 30% DBBM	Frialit 2
Karabuda et al. (2006)	DBBM + fully synthetic ceramic graft	Camlog, Xive, MIS
Lindenmüller & Lambrecht (2006)	AB/Ceros 82/AG + Ceros 82/ Algipore/AG + Algipore	ITI, Frialit 2
Peleg et al. (2006)	AB/50% AB + 50%DBBM/DFDBA/ bone cement	Zimmer Dental
Hallman & Nordin (2004)	DBBM + fibrin glue	ITI
Iturriaga & Ruiz (2004)	AB (calvarium)	Astra, 3i Osseotite, Corevent, Semados
Mazor et al. (2004)	AB + DBBM + PRP	Zimmer Dental
Peleg et al. (2004)	AB/50%AB + 50% DBBM	Zimmer Dental
Engelke et al. (2003)	AB + β-TCP	Frialit 2, IMZ, Pitt-easy, ITI
Stricker et al. (2003)	AB (iliac)	ITI
Valentini & Abensur (2003)	50% DFDBA + 50% DBBM/DBBM	IMZ
van den Bergh et al. (2000)	DFDBA	ITI
Kaptein et al. (1998)	AB (iliac block) + AB (particulated) + HA	IMZ
van den Bergh et al. (1996)	AB (iliac particulate)	ITI
Watzek et al. (1998)	AB (iliac)/AB (iliac) + HA or DBBM/ AB (iliac or oral cavity) + HA + DBBM	IMZ, Frialit 2
Zinner & Small (1996)	AB + DFDBA + HA	ITI

AB, autogenous bone; DBBM, deproteinized bovine bone mineral; DFDBA, demineralized freeze-dried bone allograft; HA, hydroxyapatite; β-TCP, β-tri-calcium phosphate; PRP, platelet rich plasma; MBCP, macroporous biphasic calcium phosphate; ICB, irradiated cancellous bone.

Table 7. **Complications accompanying sinus floor augmentation**

Authors	Complications (%)			
	Membrane perforation	Postoperative sinusitis	Partial graft failure	Total graft failure
Kim et al. (2009)	28.6	10.7	NS	NS
Kahnberg & Vannas-Löfqvist (2008)	NS	22.2	11.1	0
Lee et al. (2008)	8.6	0	NS	NS
Galindo-Moreno et al. (2007)	0	0	0	0
Krennmair et al. (2007)	58	NS	NS	NS
Marchetti et al. (2007)	0	NS	NS	NS
Karabuda et al. (2006)	13.2	NS	NS	NS
Lindenmüller & Lambrecht (2006)	11.2	3.1	0	0
Peleg et al. (2006)	NS	NS	25	0
Hallman & Nordin (2004)	14.1	2.8	NS	NS
Iturriaga & Ruiz (2004)	32.8	2.6	0	2.6
Mazor et al. (2004)	NS	NS	NS	NS
Peleg et al. (2004)	NS	0	0	0
Engelke et al. (2003)	23.7	0.8	0.8	0
Stricker et al. (2003)	37.9	0	NS	NS
Valentini & Abensur (2003)	NS	1.3	NS	NS
van den Bergh et al. (2000)	20	NS	NS	NS
Kaptein et al. (1998)	16	NS	NS	NS
van den Bergh et al. (1996)	4.8	1.6	NS	NS
Watzek et al. (1998)	10	NS	NS	NS
Zinner & Small (1996)	NS	NS	NS	NS

NS, not specified.

that occurs in 19.5% (range 0–58.3%) of sinus floor elevations (Pjetursson et al. 2008). It has been stated that perforation of the sinus membrane does not compromise the osseointegration process or the survival of dental implants placed in an augmented maxillary sinus (Karabuda et al. 2006). A correlation between sinus membrane perforation and extended postoperative sinusitis or implant loss could not be found (Kaptein et al. 1998). The present review reveals that the advent of sinusitis, partial, or total graft loss is independent of the graft material. Using AB will not protect patients from developing sinusitis or graft loss.

Resorption of graft material and subsequent repneumatization have been mentioned as reasons to choose non-resorbable or slowly resorbable BS in sinus floor augmentation. However, the data of the present review do not reveal that resorption of the graft material has an influence on implant survival (Hallman & Nordin 2004; Kim et al. 2009). The aspect of resorption does not seem to be of concern that should prompt the clinician to prefer or abandon AB.

The height of the residual alveolar ridge was the basis for the decision of a staged approach or implant placement simultaneous with sinus floor augmentation in some studies. As the thresholds for one or the other procedure were chosen arbitrarily and had no scientific basis, the implant survival was comparable for the different graft materials used. The aspects of height of the residual alveolar crest and simultaneous or delayed implant placement did not seem to contribute to the decision of whether AB should be preferred in sinus floor augmentation or not. However, it has to be kept in mind that simultaneous implant placement is less invasive than a staged approach, more cost-effective, and more time-efficient (Becktor et al. 2008). However, this is true for every graft material used.

The healing periods elapsed after the different sinus floor augmentation procedures were also chosen arbitrarily in the different studies. Longer healing periods did not increase implant survival in a relevant way. Implant survival seemed not to be influenced by the healing periods of the different graft materials. The length of the healing period of the graft material could not be identified as a reason to prefer AB over BS.

The aspect of costs cannot be ignored in sinus floor augmentation procedures. Harvesting AB increases the operating time (Peleg et al. 2004). Especially, in case of extraoral donor sites, surgery is performed

Table 8. **Implant survival rates**

Authors	Implant survival rates (%)							
	Over all	AB	BS	AB + BS	Simultaneous placement	Staged approach	Membrane coverage	No membrane coverage
Kim et al. (2009)	89.4			89.3	93.75	83.3	89.3	
Kahnberg & Vannas-Löfqvist (2008)	100	100				100		100
Lee et al. (2008)	98.46	NS	NS	NS	NS	NS	98.46	
Galindo-Moreno et al. (2007)	99			99	99.5	97.9	99	
Krennmair et al. (2007)	100			100	–	100	100	
Marchetti et al. (2007)	96.3			94.9	87.5	97.2		94.9
Karabuda et al. (2006)	95.9		95.10		NS	NS	NS	NS
Lindenmüller & Lambrecht (2006)	90	NS	NS	NS	91.7	82	NS	NS
Peleg et al. (2006)	97.9	NS	NS	NS	97.9		97.9	
Hallman & Nordin (2004)	94.5		94.5			94.5	NS	NS
Iturriaga & Ruiz (2004)	100	100				100	NS	NS
Mazor et al. (2004)	100			100	100		100	
Peleg et al. (2004)	98	98.6		97.3		98	98	
Engelke et al. (2003)	94.8			94.8	97.7	80.6	NS	NS
Stricker et al. (2003)	99.5	99.5			NS	NS	NS	NS
Valentini & Abensur (2003)	97.8		94.5		87.3	97.7	NS	NS
van den Bergh et al. (2000)	100		100			100	NS	NS
Kaptein et al. (1998)	88.2			88.2		88.2		88.2
van den Bergh et al. (1996)	100	100				100	NS	NS
Watzek et al. (1998)	95.4	94.4	100	95.4		95.4	NS	NS
Zinner & Small (1996)	98.6			98.6	98.6		NS	NS

AB, autogenous bone; BS, bone substitute; NS, not specified.

Table 9. **Systematic reviews and meta-analyses on sinus floor augmentation**

Authors	Number of studies included (*n*)	Surgical approach to sinus	Maximum follow-up period (month)	Implant survival (%)		
				Autologous bone	Bone substitute	Combination
Del Fabbro et al. (2008)	59	Lateral	144	84–97	90–96	93–95
Pjetursson et al. (2008)	48	Lateral	72	49–100	76–100	89–100
Tan et al. (2008)	19	Transalveolar	60	Not specified	Not specified	Not specified
Aghaloo & Moy (2007)	42	Lateral and transalveolar	102	87–97*	67–100*	83–93*
Chiapasco et al. (2006)	62	Lateral and transalveolar	144	61–100	85–100	75–100
Graziani et al. (2004)	6	Lateral and transalveolar	72	Not specified	Not specified	Not specified
Strietzel (2004)	72	Lateral and transalveolar	60	85–94†	89–97†	90–97†
Wallace & Froum (2003)	43	Lateral and transalveolar	NS	Not specified	Not specified	Not specified
Tong et al. (1998)	10	Lateral	60	87–93*	68–95*	90–100*

*95% confidence interval.
†Quartile 25–Quartile 75.
NS, not specified.

under general anesthesia (Watzek et al. 1998; Iturriaga & Ruiz 2004). In some studies the patients even had to be hospitalized (Marchetti et al. 2007). These different aspects lead to an increase in costs. It has to be assumed that the money spent on increased operating time, general anesthesia, and hospitalization will exceed the expenses for BS by far. Consequently, costs may not be a reason to prefer AB. However, detailed incremental cost-effectiveness analyses are needed to clarify this aspect.

From the present review, it is impossible to decide whether general diseases, smoking, or other risk factors have an influence on the implant survival rate depending on the graft material used.

Presently, it is not possible to decide whether the use of zytokines, growth factors, and BMPs will change the characteristics of AB or BS is way that one or the other material should be preferred as far as implant survival is concerned.

All in all, the current literature provides only a low level of evidence as far as the decision-making between the use of AB and BS is concerned. To date, studies are missing that are dedicated to the clarification of the influence of residual bone height, simultaneous or delayed implant placement, sinusitis, and graft resorption on implant survival in dependence of the graft material used. The aspects of donor site morbidity, disease transmission, and costs have also not been treated adequately.

Therefore, it seems that to date no clear aspects can be identified that should prompt the clinician to prefer AB over BS.

Conclusions

The available evidence neither supports nor refutes the superiority of AB over other graft materials for sinus augmentation with regard to implant survival or complications at the recipient site. Implant survival may be confounded by factors other than the graft material used for sinus floor augmentation.

References

Aghaloo, T.L. & Moy, P.K. (2007) Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *International Journal of Oral & Maxillofacial Implants* **22**: 49–66.

Becktor, J.P., Hallstrom, H., Isaksson, S. & Sennerby, L. (2008) The use of particulate bone grafts from the mandible for maxillary sinus floor augmentation before placement of surface-modified implants: results from bone grafting to delivery of the final fixed prosthesis. *Journal of Oral & Maxillofacial Surgery* **66**: 780–786.

Brown, P., Preece, M.A. & Will, R.G. (1992) "Friendly fire" in medicine: hormones, homografts, and Creutzfeldt–Jakob disease. *Lancet* **340**: 24–27.

Chiapasco, M., Zaniboni, M. & Boisco, M. (2006) Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. *Clinical Oral Implants Research* **17**: 136–159.

Cordioli, G., Mazzocco, C., Schepers, E., Brugnolo, E. & Majzoub, Z. (2001) Maxillary sinus floor augmentation using bioactive glass granules and autogenous bone with simultaneous implant placement. Clinical and histological findings. *Clinical Oral Implants Research* **12**: 270–278.

Del Fabbro, M., Rosano, G. & Taschieri, S. (2008) Implant survival rates after maxillary sinus augmentation. *European Journal of Oral Sciences* **116**: 497–506.

Engelke, W., Schwarzwaller, W., Behnsen, A. & Jacobs, H.G. (2003) Subantroscopic laterobasal sinus floor augmentation (salsa): an up-to-5-year clinical study. *The International Journal of Oral & Maxillofacial Implants* **18**: 135–143.

Galindo-Moreno, P., Avila, G., Fernandez-Barbero, J.E., Aguilar, M., Sanchez-Fernandez, E., Cutando, A. & Wang, H.L. (2007) Evaluation of sinus floor elevation using a composite bone graft mixture. *Clinical Oral Implants Research* **18**: 376–382.

Galindo-Moreno, P., Avila, G., Fernandez-Barbero, J.E., Mesa, F., O'Valle-Ravassa, F. & Wang, H.L. (2008) Clinical and histologic comparison of two different composite grafts for sinus augmentation: a pilot clinical trial. *Clinical Oral Implants Research* **19**: 755–759.

Gomes, K.U., Carlini, J.L., Biron, C., Rapoport, A. & Dedivitis, R.A. (2008) Use of allogeneic bone graft in maxillary reconstruction for installation of dental implants. *Journal of Oral and Maxillofacial Surgery* **66**: 2335–2338.

Graziani, F., Donos, N., Needleman, I., Gabriele, M. & Tonetti, M. (2004) Comparison of implant survival following sinus floor augmentation procedures with implants placed in pristine posterior maxillary bone: a systematic review. *Clinical Oral Implants Research* **15**: 677–682.

Hallman, M. & Nordin, T. (2004) Sinus floor augmentation with bovine hydroxyapatite mixed with fibrin glue and later placement of nonsubmerged implants: a retrospective study in 50 patients. *The International Journal of Oral & Maxillofacial Implants* **19**: 222–227.

Iturriaga, M.T. & Ruiz, C.C. (2004) Maxillary sinus reconstruction with calvarium bone grafts and endosseous implants. *Journal of Oral and Maxillofacial Surgery* **62**: 344–347.

Kahnberg, K.E. & Vannas-Löfqvist, L. (2008) Sinus lift procedure using a 2-stage surgical technique: I. Clinical and radiographic report up to 5 years. *The International Journal of Oral & Maxillofacial Implants* **23**: 876–884.

Kalk, W.W., Raghoebar, G.M., Jansma, J. & Boering, G. (1996) Morbidity from iliac crest bone harvesting. *Journal of Oral and Maxillofacial Surgery* **54**: 1424–1429; discussion 1430.

Kaptein, M.L., de Putter, C., de Lange, G.L. & Blijdorp, P.A. (1998) Survival of cylindrical implants in composite grafted maxillary sinuses. *Journal of Oral and Maxillofacial Surgery* **56**: 1376–1380; discussion 1380–1381.

Karabuda, C., Arisan, V. & Hakan, O. (2006) Effects of sinus membrane perforations on the success of dental implants placed in the augmented sinus. *Journal of Periodontology* **77**: 1991–1997.

Kim, Y.K., Yun, P.Y., Kim, S.G., Kim, B.S. & Ong, J.L. (2009) Evaluation of sinus bone resorption and marginal bone loss after sinus bone grafting and implant placement. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **107**: e21–e28.

Krennmair, G., Krainhofner, M., Schmid-Schwap, M. & Piehslinger, E. (2007) Maxillary sinus lift for single implant-supported restorations: a clinical study. *The International Journal of Oral & Maxillofacial Implants* **22**: 351–358.

Kübler, N.R., Will, C., Depprich, R., Betz, T., Reinhart, E., Bill, J.S. & Reuther, J.F. (1999) Comparative studies of sinus floor elevation with autologous or allogeneic bone tissue. *Mund-, Kiefer- und Gesichtschirurgie* **3** (Suppl. 1): S53–S60.

Lee, J.H., Jung, U.W., Kim, C.S., Choi, S.H. & Cho, K.S. (2008) Histologic and clinical evaluation for maxillary sinus augmentation using macroporous biphasic calcium phosphate in human. *Clinical Oral Implants Research* **19**: 767–771.

Lindenmüller, I.H. & Lambrecht, J.T. (2006) Sinus floor elevation and implantation – a retrospective study. *Schweizer Monatsschrift fur Zahnmedizin* **116**: 142–149.

Marchetti, C., Pieri, F., Trasarti, S., Corinaldesi, G. & Degidi, M. (2007) Impact of implant surface and grafting protocol on clinical outcomes of endosseous implants. *The International Journal of Oral & Maxillofacial Implants* **22**: 399–407.

Mazor, Z., Peleg, M., Garg, A.K. & Luboshitz, J. (2004) Platelet-rich plasma for bone graft enhancement in sinus floor augmentation with simultaneous implant placement: patient series study. *Implant Dentistry* **13**: 65–72.

Nkenke, E., Radespiel-Troger, M., Wiltfang, J., Schultze-Mosgau, S., Winkler, G. & Neukam, F.W. (2002) Morbidity of harvesting of retromolar bone grafts: a prospective study. *Clinical Oral Implants Research* **13**: 514–521.

Nkenke, E., Schultze-Mosgau, S., Radespiel-Troger, M., Kloss, F. & Neukam, F.W. (2001) Morbidity of harvesting of chin grafts: a prospective study. *Clinical Oral Implants Research* **12**: 495–502.

Nkenke, E., Weisbach, V., Winckler, E., Kessler, P., Schultze-Mosgau, S., Wiltfang, J. & Neukam, F.W. (2004) Morbidity of harvesting of bone grafts from the iliac crest for preprosthetic augmentation procedures: a prospective study. *The International Journal of Oral and Maxillofacial Surgery* **33**: 157–163.

Peleg, M., Garg, A.K. & Mazor, Z. (2006) Predictability of simultaneous implant placement in the severely atrophic posterior maxilla: a 9-year longitudinal experience study of 2132 implants placed into 731 human sinus grafts. *The International Journal of Oral & Maxillofacial Implants* **21**: 94–102.

Peleg, M., Garg, A.K., Misch, C.M. & Mazor, Z. (2004) Maxillary sinus and ridge augmentations using a surface-derived autogenous bone graft. *Journal of Oral and Maxillofacial Surgery* **62**: 1535–1544.

Pjetursson, B.E., Tan, W.C., Zwahlen, M. & Lang, N.P. (2008) A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *Journal of Clinical Periodontology* **35**: 216–240.

Raghoebar, G.M., Batenburg, R.H., Timmenga, N.M., Vissink, A. & Reintsema, H. (1999) Morbidity and complications of bone grafting of the floor of the maxillary sinus for the placement of endosseous implants. *Mund-, Kiefer- und Gesichtschirurgie* **3** (Suppl. 1): S65–S69.

Stricker, A., Voss, P.J., Gutwald, R., Schramm, A. & Schmelzeisen, R. (2003) Maxillary sinus floor augmentation with autogenous bone grafts to enable placement of sla-surfaced implants: preliminary results after 15–40 months. *Clinical Oral Implants Research* **14**: 207–212.

Strietzel, F.P. (2004) Sinusbodenelevation und -augmentation. *Mund-, Kiefer- und Gesichtschirurgie* **8**: 93–105.

Tadjoedin, E.S., de Lange, G.L., Lyaruu, D.M., Kuiper, L. & Burger, E.H. (2002) High concentrations of bioactive glass material (biogran) vs. autogenous bone for sinus floor elevation. *Clinical Oral Implants Research* **13**: 428–436.

Tan, W.C., Lang, N.P., Zwahlen, M. & Pjetursson, B.E. (2008) A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation part II: transalveolar technique. *Journal of Clinical Periodontology* **35**: 241–254.

Tong, D.C., Rioux, K., Drangsholt, M. & Beirne, O.R. (1998) A review of survival rates for implants placed in grafted maxillary sinuses using meta-analysis. *The International Journal of Oral & Maxillofacial Implants* **13**: 175–182.

Valentini, P. & Abensur, D.J. (2003) Maxillary sinus grafting with anorganic bovine bone: a clinical report of long-term results. *The International Journal of Oral & Maxillofacial Implants* **18**: 556–560.

van den Bergh, J.P., ten Bruggenkate, C.M., Krekeler, G. & Tuinzing, D.B. (1996) Sinusfloor elevation and grafting with autogenous iliac crest bone. *Clinical Oral Implants Research* **9**: 429–435.

van den Bergh, J.P., ten Bruggenkate, C.M., Krekeler, G. & Tuinzing, D.B. (2000) Maxillary sinus-floor elevation and grafting with human demineralized freeze dried bone. *Clinical Oral Implants Research* **11**: 487–493.

Wallace, S.S. & Froum, S.J. (2003) Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Annals of Periodontology* **8**: 328–343.

Watzek, G., Weber, R., Bernhart, T., Ulm, C. & Haas, R. (1998) Treatment of patients with extreme maxillary atrophy using sinus floor augmentation and implants: preliminary results. *The International Journal of Oral and Maxillofacial Surgery* **27**: 428–434.

Wheeler, S.L. (1997) Sinus augmentation for dental implants: the use of alloplastic materials. *Journal of Oral and Maxillofacial Surgery* **55**: 1287–1293.

Will, R.G., Ironside, J.W., Zeidler, M., Cousens, S.N., Estibeiro, K., Alperovitch, A., Poser, S., Pocchiari, M., Hofman, A. & Smith, P.G. (1996) A new variant of Creutzfeldt–Jakob disease in the UK. *Lancet* **347**: 921–925.

Zinner, I.D. & Small, S.A. (1996) Sinus-lift graft: using the maxillary sinuses to support implants. *Journal of the American Dental Association* **127**: 51–57.