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


Abstract

Objectives: The objectives of this systematic review were to assess the survival rate of implants placed in sites with transalveolar sinus floor elevation.

Material and Methods: An electronic search was conducted to identify prospective and retrospective cohort studies on transalveolar sinus floor elevation, with a mean follow-up time of at least 1 year after functional loading. Failure and complication rates were analyzed using random-effects Poisson regression models to obtain summary estimates/year proportions.

Results: The search provided 849 titles. Full-text analysis was performed for 176 articles, resulting in 19 studies that met the inclusion criteria. Meta-analysis of these studies indicated an estimated annual failure rate of 2.48% (95% confidence interval (95% CI): 1.37–4.49%) translating to an estimated survival rate of 92.8% (95% CI): 87.4–96.0%) for implants placed in transalveolarly augmented sinuses, after 3 years in function. Furthermore, subject-based analysis revealed an estimated annual failure of 3.71% (95% CI: 1.21–11.38%), translating to 10.5% (95% CI: 3.6–28.9%) of the subjects experiencing implant loss over 3 years.

Conclusion: Survival rates of implants placed in transalveolar sinus floor augmentation sites are comparable to those in non-augmented sites. This technique is predictable with a low incidence of complications during and post-operatively.

Key words: biological complications; bone augmentation; bone grafting; complications; crestal approach; dental implants; failures; longitudinal; meta-analysis; osteotome technique; peri-implantitis; sinus augmentation; sinus floor elevation; sinus grafting; success; survival; systematic review; transalveolar technique.

Accepted for publication 20 May 2008
(Lekholm and Zarb 1985) maxillary bone, resulting in better primary stability of inserted dental implants. Bone was conserved by the osteotome technique because drilling was not performed.

The bone-added osteotome sinus floor elevation (BAOSFE), also known as the “Summers technique”, may be considered to be more conservative and less invasive than the lateral approach. A small osteotomy is performed through the alveolar crest of the edentulous ridge at the inferior border of the maxillary sinus. This intrusion osteotomy procedure elevates the sinus membrane, thus creating a “tent”. This provides space for bone graft placement or blood clot formation. It should be noted that the bone grafts are placed blindly into the space below the sinus membrane. Hence, the main disadvantage of this technique is the uncertainty of possible perforations of the sinus floor (Schneiderian) membrane. However, an endoscopic study revealed that the sinus floor may be elevated up to 5 mm without perforating the sinus membrane. (Engelke & Deckwer 1997). However, other endoscopic studies have demonstrated the risk of membrane perforation while performing transalveolar sinus floor elevation (Nkenke et al. 2002, Berengo et al. 2004).

The majority of authors who reported on the osteotome technique utilized grafting materials. Grafting material is added incrementally to the osteotomy site and condensed until the desired bone height is reached. Pressure from the osteotomes caused the graft material and trapped fluids to exert hydraulic pressure on the sinus membrane causing elevation over a greater area.

Brägger et al. (2004) investigated the patterns of tissue remodelling after placement of 25 implants in 19 patients using the osteotome technique with composite xenografts and autografts. Intraoral radiographs were obtained pre-surgically and postsurgically at 3 and 12 months. The mean height of the augmented area reached apically and mesially to the implants was 1.52 mm at surgery, but was reduced significantly to 1.24 mm at 3 months and 0.29 mm after 12 months. It was concluded that the grafted area apical to the implants underwent resorption and remodelling. The original outline of the sinus was eventually consolidated and replaced by a new cortical plate.

On the other hand, studies in monkeys (Boyne 1993) reported that implants protruding into the maxillary sinus following elevation of the sinus membrane without grafting material exhibited spontaneous bone formation below the sinus membrane. Implants with rounded apices showed spontaneous bone formation extending around the implants when they penetrated only 2–3 mm into the maxillary sinus. When the same implants penetrated 5 mm or more into the maxillary sinus, only a partial (50%) growth of new bone was seen towards the apex of the implant. Moreover, implant design appeared to influence the amount of spontaneous bone formation because implants with open apices or deep-threaded configurations did not reveal substantial new bone formation.

In a clinical study (Lelebioglu et al. 2005), implants were installed into the sinuses of 40 patients using an osteotome technique with no graft or cushion material. The authors reported a mean gain of alveolar bone height in scanned panoramic radiographs of 3.9 ± 1.9 mm.

In a retrospective study, sinus floor remodelling after implant insertion using a modified osteotome technique without grafting material was assessed radiographically (Schmidlin et al. 2008). Twenty-four patients were available for follow-up. The implant survival rate was 100%. Bone fill around the implants was measured and compared with baseline digital radiographs. The mean height of the newly formed bone was 2.2 ± 1.7 mm mesially and 2.5 ± 1.5 mm distally, or expressed as a percentage of new bone formation, 86.3 ± 22.1% and 89.7 ± 13.3%, respectively.

Since the crestal approach of sinus floor elevation was introduced (Tatum 1986), several studies have reported on this technique. The studies all reported high survival rates of implants placed utilizing the transalveolar approach (Komarnyckyj and London 1998, Rosen et al. 1999, Cosci and Luccioli 2000, Ferrigno et al. 2006, Pjetursson et al. 2008).

In a multicentre retrospective study (Rosen et al. 1999) that evaluated the application of the “Summers technique” for placement of 174 implants in 101 patients, the survival rate was 96%, when residual bone height was 5 mm or more, but declined to 85.7% when residual bone height was 4 mm or less.

In a recent study (Ferrigno et al. 2006), survival and success rates of 588 implants placed in 323 consecutive patients with a residual bone height ranging from 6 to 9 mm were evaluated. After a mean observation period of 5 years, the survival and success rates were 94.8% and 90.8%, respectively. During the study period, only 13 perforations of the sinus membrane were detected, yielding a perforation rate of only 2.2%. The authors also concluded that the installation of short implants in conjunction with osteotome sinus floor elevation is predictable and may reduce the indications for more invasive and complex procedures, such as the sinus floor elevation by the lateral approach.

Moreover, a systematic review (Emmerich et al. 2005) evaluated the effectiveness of sinus floor elevation using osteotomes. The inclusion criteria considered studies that had >10 patients and at least 6 months of functional loading. Eight studies met these inclusion criteria. Within the limits of the long-term data presented, the reviewers concluded that the short-term success rates were similar to the success rates of implants conventionally placed in the partially edentulous patients (96.0% after 36 months). Long-term outcomes (>5 years) of implants placed with the osteotome technique are still scarce. As the database was heterogeneous, no statistical analysis could be performed with regard to the different surgical techniques, implant types and grafting materials.

The main objectives of this systematic review were, therefore, to assess the survival rate of implants placed in sites with transalveolar sinus floor augmentation and to evaluate the incidence of surgical and post-operative complications related to this procedure.

Material and Methods
Search strategy and study selection
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Manual searches of the bibliographies of all full-text articles and related reviews, selected from the electronic search, were also performed.

From this search, no randomized-controlled clinical trials (RCTs) were available comparing survival rates of implants placed in transalveolar sinus augmentation sites with implants placed in non-grafted sites.

**Inclusion criteria**

Because of the absence of RCTs, this systematic review included prospective and retrospective cohort studies. The additional inclusion criteria for study selection were:

- publications in the dental literature, based on human subjects without language restriction,
- studies based on transalveolar sinus floor augmentation,
- studies with a mean follow-up time of at least 1 year of functional loading,
- studies reporting on implant survival rate,
- studies with a minimum of 10 patients,
- studies with absence of multiple interventions (like simultaneous ridge augmentations),
- studies with clearly defined survival or success criteria.

Studies on implants in sinuses grafted via the lateral approach were excluded from this analysis and will be analyzed separately (Pjetursson et al. 2008c).

**Selection of studies**

Titles and abstracts of the searches were initially screened by two independent reviewers (B. E. P., W. C. T.) for possible inclusion in the review. The full-texts of all studies of possible relevance were then obtained for independent assessment by the reviewers. Any disagreement was resolved via discussion. The $\kappa$ values were 0.76 and 0.53 at the title and abstract levels, respectively.

Figure 1 describes the process of identifying the 19 studies selected from an initial yield of 849 titles. Data were extracted independently by two reviewers using a data extraction form.

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**Excluded studies**

Of the 176 full-text articles examined, 157 were excluded from the final analysis (see reference list). The main reasons for exclusion were (Fig. 1):

- not reporting on transalveolar sinus floor elevation,
- studies on the lateral technique or reporting on two-stage approach,
- mean follow-up < 1 year in function, 
- sample size of less than 10 patients and 
- multiple publications on the same patient cohorts.

**Data extraction**

From the 19 studies included, information on the survival of implants placed in combination with transalveolar sinus floor elevation was retrieved. Survival was defined as implants remaining *in situ* at the follow-up, irrespective of the conditions of the surrounding tissues. Failure was defined as implants that were lost before or after function.

Surgical complications like Schneiderian membrane perforation and post-operative infection following the procedure were also evaluated.

**Statistical analysis**

Failure and complication rates were calculated by dividing the number of events (failures or complications) in the numerator by the total exposure time (implant-time) in the denominator.

The numerator was usually extracted directly from the publication. The total exposure time was calculated by taking the sum of:

1. Exposure time of implants that could be followed for the whole observation time.
2. Exposure time up to a failure of implants that were lost.
(3) Exposure time up to the end of observation time for implants that did not complete the observation period due to reasons such as death, change of address, refusal to participate in the follow-up visit, chronic illnesses, missed appointments and work commitments.

For each study, event rates for implants were calculated by dividing the total number of events by the total implant exposure time in years. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of implant exposure years, and Poisson regression with a logarithmic link-function and total exposure time per study as an offset variable were used (Kirkwood & Sterne 2003a).

Robust standard errors were calculated to obtain 95% confidence intervals (95% CI) of the summary estimates of the event rates. The Spearman goodness-of-fit statistics and associated p-value were calculated to assess the heterogeneity of the study-specific event rates. If the goodness-of-fit p-value was below 0.05, indicating heterogeneity, random-effects Poisson regression (with γ-distributed random effects) was used to obtain a summary estimate of the event rates. One-year survival proportions were calculated via the relationship between event rate and survival function $S(T) = \exp(-T \times \text{event rate})$, by assuming constant event rates (Kirkwood & Sterne 2003b). The 95% CI for the survival proportions were calculated by using the 95% confidence limits of the event rates.

All analyses were performed using Stata®, version 8.2 (Stata Corp., College Station, TX, USA).

Results

Included studies

A total of 19 studies on implants placed in transalveolar sinus floor augmented sites were included in the analysis. The characteristics of the selected studies are shown in Table 1.

These studies reported on 19 different patient cohorts. The oldest study was published in 1997, and the median year of publication was 2005. Nine of the studies were prospective, and the remaining 10 were retrospective (Table 1).

The studies included around 2830 patients between the age of 17 and 90 years with 4388 implants. The studies were conducted both in institutional environments as well as in private practices, with two multicentre studies available (Table 1).

Surgical approach

Transalveolar sinus floor elevation was performed mainly utilizing osteotomes. One study in a private centre, however, advocated the use of hydraulic sinus condensing (Chen & Cha 2005).

Grafting material

A variety of graft materials were used. Three studies performed the procedure without graft placement. One study did not report on the graft used. In the other studies, some form of graft materials was used. Various types of grafts were used in two studies. Collagen was used in two studies, deproteinized bovine bone mineral (DBBM) was used in five studies and autogenous bone graft was used in two studies. Five studies used combinations of grafts, with one study using autogenous bone graft and Bioglass® (NovaBorie Products LLC, Jacksonville, Florida, USA), one study using autogenous bone graft and DBBM, one study using autogenous bone graft, deproteinized freeze-dried bone allograft and tri-calcium phosphate and another study using autogenous bone graft, demineralized freeze-dried bone allograft and antibiotics in the graft.

Survival of implants

Of the 4388 implants placed, 103 were lost in total, with 55 implants lost before loading and 28 implants lost after at least 1 year in function. Two studies did not differentiate the time of implant failure. The estimated study-specific 3-year survival proportion varied between 57.0% and 100% (Table 2).

The estimated failure rate per 100 implant years ranged from 0% to 18.8% (Table 2), and the summary estimate based on random-effects Poisson regression was 2.48 failures per 100 implant years (95% CI: 1.37–4.49%) (Table 2). The summary estimate for the survival after 3 years for implants was 92.8% (95% CI: 87.4–96.0%) (Table 2). The survival rate of implants inserted with this technique decreased to 91.8% (95% CI: 85.7–95.4%) when the three studies with residual bone height of more than 8 mm were excluded.

Further analysis on the subject level based on nine studies reporting on 545 patients with 770 implants revealed an estimated annual failure of 3.71% (95% CI: 1.21–11.38%), translating to 10.5% (95% CI: 3.6–28.9%) of the subjects experiencing implant loss over 3 years (Table 3).

Because of the heterogeneity of the studies, no statistical analysis could be performed with regard to the different surgical techniques, implant surfaces and grafting materials.

Surgical complications

Schneiderian membrane perforation was the most commonly reported surgical complication. Information on membrane perforation could be extracted from eight of the 19 included studies, with 1621 implants. Membrane perforation varied between 0% and 21.4%, with a mean of 3.8% (Table 4).

Post-operative complications

The most common post-operative complication was post-operative infection. Only six out of the 19 studies, with 884 implants, reported on post-operative infection. Post-operative infection ranged between 0% and 2.5%, with a low mean of 0.8% (Table 4). Other complications reported included post-operative haemorrhage, nasal bleeding, blocked nose, haematomas and loosening of cover screws resulting in suppurative. No air embolism was reported in the study using hydraulic sinus condensing (Chen & Cha 2005).

Discussion

This systematic review is the second part of a series addressing the survival and complication rates of grafts and implants placed in sinus augmentation sites via the lateral and transalveolar techniques. In the absence of RCTs, a lower level of evidence with prospective and retrospective cohort studies was used.

Instead of performing a formal quality assessment of the included studies and sensitivity analysis, this review used stringent inclusion criteria.

Based on 19 included studies reporting on 4388 implants after a mean
<table>
<thead>
<tr>
<th>Study</th>
<th>Year of publication</th>
<th>Study design</th>
<th>Setting</th>
<th>No. of patients</th>
<th>Mean age (years)</th>
<th>Age range</th>
<th>Residual bone height (mm)</th>
<th>Surgical procedure</th>
<th>Antibiotic prophylaxis</th>
<th>Graft materials</th>
<th>Implant types</th>
<th>Drop-out (in percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pjetursson et al.</td>
<td>2008b</td>
<td>Prosp.</td>
<td>Institution</td>
<td>181</td>
<td>54.9</td>
<td>17–90</td>
<td>7.5</td>
<td>Post or none</td>
<td>DBBM</td>
<td>NG</td>
<td>DBBM</td>
<td>10</td>
</tr>
<tr>
<td>Krennmair et al.</td>
<td>2007</td>
<td>Retros.</td>
<td>Institution</td>
<td>14</td>
<td>54.6</td>
<td>29–86</td>
<td>9.6</td>
<td>NR</td>
<td>DBBM</td>
<td>Frialit-2</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>Levine et al.</td>
<td>2007</td>
<td>Retros.</td>
<td>Multicenter</td>
<td>NR</td>
<td>NR</td>
<td>18–78</td>
<td>NR</td>
<td>NR</td>
<td>Pre, post</td>
<td>ABG-50%BG</td>
<td>ITI</td>
<td>NR</td>
</tr>
<tr>
<td>Stavropoulos et al.</td>
<td>2007</td>
<td>Prosp.</td>
<td>Institution</td>
<td>26</td>
<td>59.3</td>
<td>NR</td>
<td>2–9</td>
<td>Post</td>
<td>DBBM</td>
<td>NR</td>
<td>Frialit-2</td>
<td>0</td>
</tr>
<tr>
<td>Zhao et al.</td>
<td>2007</td>
<td>Prosp.</td>
<td>Institution</td>
<td>104</td>
<td>NR</td>
<td>21–69</td>
<td>9.16</td>
<td>NR</td>
<td>NR</td>
<td>ITI</td>
<td>Frialit-2</td>
<td>NR</td>
</tr>
<tr>
<td>Ferrigno et al.</td>
<td>2006</td>
<td>Prosp.</td>
<td>Institution</td>
<td>323</td>
<td>51.2</td>
<td>34–73</td>
<td>6–9</td>
<td>Post</td>
<td>ABG</td>
<td>NR</td>
<td>ITI</td>
<td>2</td>
</tr>
<tr>
<td>Nedir et al.</td>
<td>2006</td>
<td>Prosp.</td>
<td>Institution</td>
<td>17</td>
<td>54.2</td>
<td>38–69</td>
<td>5.4</td>
<td>Pre, post</td>
<td>NG</td>
<td>NR</td>
<td>ITI</td>
<td>0</td>
</tr>
<tr>
<td>Chen &amp; Cha</td>
<td>2005</td>
<td>Retros.</td>
<td>Private practice</td>
<td>1100</td>
<td>NR</td>
<td>NR</td>
<td>Min</td>
<td>Pre, post</td>
<td>BioHorizons Xive</td>
<td>NR</td>
<td>Endopore</td>
<td>NR</td>
</tr>
<tr>
<td>Deporter et al.</td>
<td>2005</td>
<td>Retros.</td>
<td>Institution, private practice</td>
<td>70</td>
<td>NR</td>
<td>NR</td>
<td>4.2</td>
<td>Post</td>
<td>DBBM</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Leblebicioglu et al.</td>
<td>2005</td>
<td>Prosp.</td>
<td>Institution</td>
<td>40</td>
<td>46.7</td>
<td>NR</td>
<td>9.1</td>
<td>Pre, post</td>
<td>ABG (10–75%) + DBBM</td>
<td>Frialit-2</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>Toffler</td>
<td>2004</td>
<td>Prosp.</td>
<td>Institution</td>
<td>167</td>
<td>56.8</td>
<td>27–82</td>
<td>7.1</td>
<td>Pre, post</td>
<td>NG</td>
<td>Frialit-2</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>Winter et al.</td>
<td>2002</td>
<td>Retros.</td>
<td>Private practice</td>
<td>34</td>
<td>60.7</td>
<td>31–78</td>
<td>2.87</td>
<td>Pre only</td>
<td>Collagen sponge</td>
<td>NR</td>
<td>Frialit-2</td>
<td>NR</td>
</tr>
<tr>
<td>Cavicchia et al.</td>
<td>2001</td>
<td>Retros.</td>
<td>Private practice</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>≥5</td>
<td>Pre, post</td>
<td>ABG+CS</td>
<td>Frialit</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Rosen et al.</td>
<td>1999</td>
<td>Retros.</td>
<td>Multicenter</td>
<td>101</td>
<td>56.1</td>
<td>31–81</td>
<td>Min 3 mm</td>
<td>NR</td>
<td>ABG</td>
<td>DBBM</td>
<td>Imz</td>
<td>NR</td>
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<tr>
<td>Bruschi et al.</td>
<td>1998</td>
<td>Retros.</td>
<td>Private practice</td>
<td>303</td>
<td>50</td>
<td>NR</td>
<td>5–7</td>
<td>Pre, post</td>
<td>Collagen sheet</td>
<td>IMZ</td>
<td>IMZ</td>
<td>NR</td>
</tr>
<tr>
<td>Komarnyckyj &amp; London</td>
<td>1998</td>
<td>Prosp.</td>
<td>Private perio practice</td>
<td>16</td>
<td>NR</td>
<td>NR</td>
<td>5.5</td>
<td>Pre, post</td>
<td>ABG</td>
<td>Frialit</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>Zitzmann &amp; Scharer</td>
<td>1998</td>
<td>Prosp.</td>
<td>Institution</td>
<td>20</td>
<td>58</td>
<td>36–75</td>
<td>≥6 mm</td>
<td>Pre, post</td>
<td>DBBM</td>
<td>ABG</td>
<td>Bränenmark</td>
<td>0</td>
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<tr>
<td>Coatam &amp; Krieger</td>
<td>1997</td>
<td>Prosp.</td>
<td>Private practice</td>
<td>77</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>Pre, post</td>
<td>DBBM+ABG+abic</td>
<td>Bio-Vent (Paragon)</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

ABG, autogenous bone graft; ABt, antibiotics; BG, Bioglass; CS, collagen sponge; DBBM, deproteinized bovine bone mineral; DFDBA, demineralized freeze-dried bone allograft; FDBA, freeze-dried bone allograft; HA, Hydroxyapatite; TCP, tri-calcium phosphate; Min, minimum; NG, no graft; NR, not reported; Pre, pre-operative; Post, post-operative; Prosp., prospective; Retrosp., retrospective.
follow-up time of 3.1 years, the annual failure rate was 2.48%, translating into a 3-year implant survival of 92.8%. This is slightly lower than the percentage presented in an earlier systematic review on implants in transalveolar sinus floor-augmented sites (Emmerich et al. 2005) with 96% after 3 years. This difference between the percentage found in the present study and the former data set is most likely due to the more stringent entry criteria applied in the present study (at least 1 year of functional loading). Moreover, only eight studies with 1139 implants as opposed to 19 studies with 4388 implants of the present review may have contributed to the less optimistic proportions presented.

It was evident that the failure rate of the implants placed into sites with transalveolar sinus floor augmentation increased and correlated with reduced residual bone height and reduced implant length as described in a multicentre retrospective study (Rosen et al. 1999) that reported a survival rate of 96%, when the residual bone height was 5 mm or more, but decreased to 85.7%, when the residual bone height was 4 mm or less. Similar results were also reported in a recent prospective study, where the survival rate for short 6-mm implants inserted with the transalveolar osteotome technique was only 57% (Pjetursson et al. 2008b).

There is still controversy regarding the necessity of a grafting material in order to maintain the space for new bone formation after elevating the sinus membrane utilizing the transalveolar technique. In the present systematic review, 15 out of the 19 studies utilized some form of grafting material and three studies did not use any grafting material at all.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year of publication</th>
<th>Total no. of implants</th>
<th>Mean follow-up time (years)</th>
<th>No. of failure before loading</th>
<th>Total implant exposure time</th>
<th>Estimated failure rate (per 100 implant years)</th>
<th>Estimated survival after 3 years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pjetursson et al.</td>
<td>2008b</td>
<td>252</td>
<td>3.2</td>
<td>6</td>
<td>697</td>
<td>0.86</td>
<td>97.5</td>
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<td>Krennmaier et al.</td>
<td>2007</td>
<td>14</td>
<td>3.7</td>
<td>0</td>
<td>52</td>
<td>0</td>
<td>100</td>
</tr>
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<td>Stavrropoulos et al.</td>
<td>2007</td>
<td>35</td>
<td>1</td>
<td>6</td>
<td>32</td>
<td>18.8</td>
<td>57.0</td>
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<td>Levine et al.</td>
<td>2007</td>
<td>45</td>
<td>1.7</td>
<td>5</td>
<td>77</td>
<td>6.49</td>
<td>82.3</td>
</tr>
<tr>
<td>Zhao et al.</td>
<td>2007</td>
<td>126</td>
<td>3.5</td>
<td>0</td>
<td>441</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ferrigno et al.</td>
<td>2006</td>
<td>588</td>
<td>5</td>
<td>9</td>
<td>2641</td>
<td>0.11</td>
<td>99.0</td>
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<td>Nedir et al.</td>
<td>2006</td>
<td>25</td>
<td>1</td>
<td>0</td>
<td>25</td>
<td>0</td>
<td>100</td>
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<td>Chen &amp; Cha</td>
<td>2005</td>
<td>1557</td>
<td>3.2</td>
<td>8</td>
<td>4957</td>
<td>0.16</td>
<td>95.5</td>
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<td>Deporter et al.</td>
<td>2005</td>
<td>104</td>
<td>3.1</td>
<td>2</td>
<td>323</td>
<td>0.62</td>
<td>98.2</td>
</tr>
<tr>
<td>Leblebicioglu et al.</td>
<td>2005</td>
<td>75</td>
<td>2</td>
<td>2</td>
<td>152</td>
<td>1.32</td>
<td>96.1</td>
</tr>
<tr>
<td>Toffler</td>
<td>2004</td>
<td>276</td>
<td>2</td>
<td>14</td>
<td>558</td>
<td>1.79</td>
<td>94.8</td>
</tr>
<tr>
<td>Winter et al.</td>
<td>2002</td>
<td>58</td>
<td>1.5</td>
<td>5</td>
<td>86</td>
<td>5.81</td>
<td>84.0</td>
</tr>
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<td>Cavicchia et al.</td>
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Summary estimate (95 % CI)*

- Based on random-effects Poisson regression, test for heterogeneity p < 0.0001.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year of publication</th>
<th>Total no. of subjects</th>
<th>Mean follow-up time (years)</th>
<th>Total no. of implants</th>
<th>No. of failure</th>
<th>Total subject exposure time</th>
<th>Estimated failure rate (per 100 subject years)</th>
<th>Estimated success after 3 years (%)</th>
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<tr>
<td>Pjetursson et al.</td>
<td>2008b</td>
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<td>Krennmaier et al.</td>
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<td>Zhao et al.</td>
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<td>89.5</td>
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</table>

Summary estimate (95 % CI)*

- Based on random-effects Poisson regression, test for heterogeneity p < 0.0001.

CI, confidence interval.
In one of the studies (Leblebicioglu et al. 2005), implants were installed with no graft or cushion material. The authors reported a mean gain of alveolar bone height in scanned panoramic radiographs of 3.9 ± 1.9 mm.

Pjetursson et al. (2008a) compared a group of 164 implants installed by the transalveolar technique with no grafting materials being placed with another group of 88 implants installed by the transalveolar technique where DBBM was placed. The authors reported a gain of radiographic bone height of 1.7 and 4.1 mm, respectively, when assessing these parameters on digitized periapical radiographs.

When performing sinus floor elevation, the risk of complications must be considered and the appropriate treatment must be foreseen. The most frequent complication was perforation of the sinus membrane, which occurred in 3.8% of the procedures. Post-operative infection was rare with 0.8%.

Instead of performing a formal quality assessment of the included studies and sensitivity analysis, this review used stringent inclusion criteria. There was no language restriction in the present systematic review, which resulted in inclusion of articles in Mandarin as well as in English, German, Dutch, Italian and French.

In the absence of RCTs, a lower level of evidence, i.e. prospective and retrospective cohort studies were included in the present systematic review.

One limitation of the present review is the assumption of a constant annual event rate throughout the follow-up time after placement of the reconstruction. Hence, when interpreting the results, it must be kept in mind that the mean observation period was an average of 3.1 years.

It must be acknowledged that the percentage of implant failures is usually higher in the first year. This, in turn, means that annual failure rates based on a mean follow-up time of 3 years should not be extrapolated to follow-up times assessed for decades. There is a definite lack of long-term follow-up studies reporting on implants placed into sites with an augmented sinus floor using the transalveolar technique, as the longest mean follow-up time in the present review was only 4.3 years (Bruschi et al. 1998).

The present systematic review revealed several shortcomings in the clinical studies. Many of the studies on the survival of implants placed in sinus-grafted sites failed to report the original residual bone height and graft failures, if any.

There is a need for a long-term clinical trial (≥5 years) of implants inserted in combination with transalveolar sinus floor elevation. Furthermore, the question of whether different surgical techniques, implant types and grafting materials would improve the outcomes remains open, and future research is needed. RCTs with sufficient statistical power comparing transalveolar sinus floor elevations with and without grafting materials would be of great value.

The following conclusions can be drawn from this systematic review:

1. The estimated annual implant failure rate was 2.5% (95% CI: 1.4–4.5%). This translated into a 3-year implant survival of 92.8% (95% CI: 87.4–96.0%).
2. The survival rate appeared to decrease with decreasing residual bone height.
3. Analysis on the subject-level revealed an estimated annual failure of 3.71% (95% CI: 1.21–11.38%), translating to 10.5% (95% CI: 3.6–28.9%) of the subjects experiencing implant loss over 3 years.
4. Perforation of the sinus membrane occurring in 3.8% of the procedures was the most frequently reported complication. The mean incidence of post-operative graft infection was 0.8%.

Acknowledgements
This study has been supported by the Clinical Research Foundation (CRF) for the Promotion of Oral Health, University of Berne, Switzerland. Dr. Wah Ching Tan was an ITI Scholar for the year 2006/2007 (ITI Foundation, Basel, Switzerland, Educational grant).

References


**List of excluded full-text articles and the reason for exclusion**


Maxillofacial Implants 11, 512–521. Exclusion criteria: sinus augmentation via the lateral technique.


Fugazzotto, P. A. & De, P. S. (2002) Sinus floor augmentation at the time of maxillary molar...


less than 10 patients. Exclusion criteria: sinus augmentation via the lateral technique.


criteria: sinus augmentation via the lateral technique.


Systematic review of sinus floor elevation

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**Clinical Relevance**

**Scientific rationale for the study:** With increasing popularity of transalveolar sinus floor elevation, an analysis of the implant survival rate in such sites and complications of the procedure would be of great value.

**Principal findings:** Meta-analyses of the selected studies revealed an estimated 3-year implant survival in transalveolar sinus augmented sites to be comparable to that in non-augmented sites. Incidences of surgical complications were very low.

**Practical implications:** Implant installation in combination with transalveolar sinus floor elevation proved to be a predictable option in sites with inadequate bone height for standard implant placement and is less invasive than lateral approach sinus floor elevation.