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An economic evaluation of different sinus lift techniques

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Abstract

Purpose: To identify the most cost-effective approach to sinus lifting on the basis of currently available evidence.

Methods: We incorporate the costs and clinical outcomes of nine different sinus lift techniques within a decision tree model in which costs are based on insurance regulations in Germany and health outcomes follow two recent meta-analyses. The most cost-effective treatment option is identified on the basis of the maximum net benefit criterion. Uncertainties regarding health outcomes are incorporated via probabilistic sensitivity analysis based on Monte-Carlo simulation.

Results: When there are no financial restrictions, the optimum treatment strategy is the lateral approach with autogenous particulate bone and a resorbable membrane. When, however, monetary resources for sinus-floor elevation are scarce, the most cost-effective option is the transalveolar technique without bone grafting. Only if relatively high costs can be afforded or if initial bone height at implant site is below 5 mm is the maximum net benefit achieved by lateral approaches.

Conclusions: On the basis of currently available evidence, the transalveolar technique is advisable when monetary resources for sinus-floor elevation are scarce and initial bone height is sufficiently high. Lateral approaches are primarily recommended for lower pre-operative bone heights.

Key words: cost-effectiveness; decision analytical modelling; maximum net benefit; probabilistic sensitivity analysis; sinus floor elevation

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Sinus-floor elevation is a frequently proposed treatment option for implant insertion into the posterior maxilla when vertical bone height is reduced, and yet health care decision makers must often compromise between the attainable level of treatment effectiveness and the monetary resources available (Drummond et al. 2005). This specifically applies to sinus-floor elevation, in which a variety of treatment options exist, with substantial differences in cost. Specifically, the cost differential originates from the techniques used to gain access to the sinus floor (lateral or transalveolar methods), the use of different bone-grafting materials (autologous bone block/chippings or bone substitutes), and the application of synthetic membranes for guided bone regeneration. Given this variety of different treatment strategies, it is still open to scrutiny as to which the options can be regarded as optimum when monetary resources for oral health services are limited. To the best of our knowledge, the cost-effectiveness of different sinus lift techniques has never been investigated, even though it is relevant to the clinician who wants to offer good ''value for money'' to the patient. The purpose of this study is, therefore, to identify the most cost-effective approach for sinus-floor elevation on the basis of currently available evidence.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.
S. L. and C. M. F. are both affiliated to the University of Heidelberg. S. L. is also affiliated to MEA, which is funded two-thirds through public third-party means. MEA's basic funding is provided by the state of Baden-Württemberg and the German Insurance Association.

Methods

The perspective considered in this study is that of a decision maker who seeks optimization from a societal perspective (Claxton et al. 2000), i.e. by comparing the benefits to and costs for a society resulting from application of sinus-floor elevation. We assume that the decision-making process is taking place in Germany and model the data within a decision tree (Buxton et al. 1997).

Health outcomes

Identification of clinical outcome data

A literature search via PubMed/Medline (16 November 2009) found four meta-analyses for the search terms ''sinus-floor elevation'' and ''sinus lift''. One of these is a report on histomorphometric outcomes (Handschel et al. 2009) and another focuses only on the transalveolar approach (Emmerich et al. 2005). Because we seek

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to compare implant survival after lateral and transalveolar sinus lift approaches, we exclude these two studies for the purpose of our investigation. The remaining two studies were conducted by the same team of authors and follow the same systematic approach. Although one focuses on lateral sinus-floor elevation and the other on the transalveolar technique, the analytical standards of both studies are identical. The two studies are:

Study A: Pjetursson et al. (2008): A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation – Part I: Lateral approach.

Study B: Tan et al. (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.

We are aware that a more extensive literature review using other search engines, for example EMBASE or the COCHRANE library, may furnish more evidence. The two studies we chose seem, however, highly representative of the literature in the field and should, thus, be sufficient for the focus of this paper, i.e. to provide an economic perspective on sinus-floor elevation (rather than conducting a full systematic literature review). We include the evidence from these two studies for the purpose of our investigation. Specifically, both studies report the probabilities of implant survival, membrane perforation, and infection after sinus-floor elevation. However, while membrane perforation and infection can only be considered surrogate outcomes, implant survival reflects the true outcome of sinus lifting (Prentice 1989, Fleming & DeMets 1996). Therefore, we rely on reported 3-year implant survival after sinus-floor elevation (Table 1) and transform these into ''expected months of implant survival'' according to the formula (Bland 2000):

$$3ySR \times 36,$$

where 3ySR is the 3-year implant survival rate as reported in the systematic reviews and 36 refers to the time period (36 months) to which the above survival rates refer.

Further particularities of these systematic reviews should be noted. First, Study A identifies significantly longer survival of rough-surfaced compared with machine-surfaced implants. Because the latter no longer seem to be prominent in contemporary implant dentistry, we consider the evidence for rough-surfaced implants only. Study A presents appropriate estimates subject to different bone-grafting materials. With regard to application of membranes for guided bone regeneration, however, Study A only provides an aggregate estimate – when a membrane is not placed, the implant survival rate is 9.3 percentage points lower than when a membrane is placed (irrespective of the bone-graft type). We thus assume that refraining from membrane application will always result in a 9.3 per cent point reduction in implant survival relative to the first-mentioned (graft-specific) implant survival, implying that the latter equates to the case where a membrane is utilized.

Second, Study A also explores outcome differences in response to the different timing of implant placement after lateral sinus-floor elevation: the two-stage approach (where after sinus lifting a period of bone healing is allowed before implant insertion) is shown to yield a 2.4% point increase in the 3-year implant survival rate in comparison with the one-stage technique (where the implant is placed simultaneously with sinus lifting). Note that these estimates are, again, only aggregate estimates that do not differentiate between various bone-grafting materials. We define the one-stage technique to correspond with the values for graft-specific implant survival (Table 1).

Third, because Study B could not identify any difference between implant survival in alternative bone-grafting approaches for transalveolar sinus-floor elevation or for different implant surfaces, we consider only the transalveolar approach without bone grafting, because all other transalveolar techniques lead to higher costs and are, thus, dominated strategies. In health economics, a treatment alternative that is more expensive but does not confer greater health gain than the alternative strategy follows the notion of being ''dominated'' (Drummond et al. 2005).

Finally, both studies only report on 3-year implant survival rates. The reason for this short follow-up is the absence of comprehensive long-term evidence after sinus lifting. Nevertheless, a long-term perspective is likely to have a substantial effect on considerations of cost-effectiveness. Therefore, we intend to provide a complementary perspective in addition to the 3-year time horizon. For implants inserted into native bone, most failures are usually observed in the initial phase after implant placement (see e.g. Weyant & Burt 1993). To date, however, no comprehensive long-term data are available for implant survival in augmented bone. On the one hand, some indications suggest that long-term survival rates are lower for implants placed in augmented as compared to pristine sites (Tonetti & Hämmerle 2008). On the other, evidence from studies with a mean follow-up period of 2.8 years shows that most implant losses after sinus lifting occur in the first post-operative year and, thus, a standard linear extrapolation based on initial-phase survival rates should not be considered suitable for predicting long-term implant survival after sinus-floor elevation (Pjetursson et al. 2008). Within the limitations of available evidence and even if the level of long-run implant survival may significantly differ between implants placed in pristine and augmented bone, it yet appears reasonable to assume that hazard rates of implants placed in native and regenerated bone both follow a similar dynamic (highest rate of implant failure during the initial phase after implant insertion). Accordingly, we implement a tailored extrapolation to predict 15-year implant survival, i.e. we infer that the difference between implant survival becomes apparent within the first 3 years after sinus lifting and that, after this initial phase, consecutive failure rates no longer differ between alternative sinus-floor elevation techniques.

Table 1. Three-year implant survival rates after different sinus lift techniques

	Survival rate (%)	95% confidence interval
Lateral approach: bone substitute only	96.7	[90.8; 98.8]
Lateral approach: autologous/substitute bone mix	96.8	[94.7; 98.0]
Lateral approach: autogenous particulate bone	99.8	[98.7; 100]
Lateral approach: autogenous bone block	96.3	[89.5; 99.2]
Transalveolar approach	92.8	[87.4; 96.0]

Values excerpted from Pjetursson et al. (2008) and Tan et al. (2008).

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The role of initial bone height

In addition to the two systematic reviews outlined above, previous clinical literature has been emphasizing the crucial importance of initial bone height for the success of sinus-floor elevation. First, it has been described that for cases where residual bone height at the implant site is below a certain threshold level, the transalveolar technique results in markedly reduced implant survival, and should, thus, not be applied. Frequently, a threshold level of 5–6 mm has been discussed below which the transalveolar technique should be avoided (Misch 1987, Hirsch & Ericsson 1991, ten Bruggenkate & van den Bergh 1998, van den Bergh et al. 1998, Rosen et al. 1999, Nkenke et al. 2002, Toffler 2004a).

Second, several authors have been reporting that, when residual bone height at the implant site is comparably low, implant insertion simultaneous with sinus lifting does not facilitate sufficient initial implant stability. Therefore, a two-stage approach is recommended, i.e. after sinus lifting, a period of bone healing should be allowed before implants are placed. The threshold below which such a two-stage approach is advised is often referred to as being between 4 and 5 mm (Smiler et al. 1992, Fugazzotto 1994, Zitzmann & Scharer 1998, Peleg et al. 1999, Mazor et al. 2000, Toffler 2004a, b, Woo & Le 2004).

Third, a recent meta-regression analysis (Chao et al. 2010) has shown a positive association between the initial alveolar bone height and the implant survival rates for lateral window techniques. The authors report that implant survival increases with initial bone height whenever the latter is 5 mm or below. For values above 5 mm, though, they describe that implant survival is stable and independent of residual bone height. Note that the authors report parameter estimates for the lateral window technique that aggregate over different bone grafting materials. Moreover, they could not prove an association between initial bone height and implant survival for the transalveolar approach.

Definition of clinical scenarios for economic modelling

In consideration of the evidence outlined above, we define the following two base case scenarios that will be incorporated for economic modelling:

Base case scenario A: initial bone height is above 5 mm.

Base case scenario B: initial bone height is below 5 mm.

Particularly, we specify that a preoperative bone height above 5 mm enables both lateral and transalveolar sinus lift techniques; in either case, implants are placed simultaneously with sinus lift treatment. Moreover, following the evidence from previous clinical literature, we assume that implant survival rates do not vary with residual bone heights (given that bone height >5 mm).

When the initial bone height is below 5 mm, however, the transalveolar approach will no longer be considered a treatment alternative; with lateral techniques, moreover, a delayed implant placement is chosen (two-stage approach). We also consider that implant survival after lateral sinus lift techniques decreases with declining preoperative bone height (given the latter being <5 mm). However, in this clinical scenario, we solely compare lateral techniques against each other; in addition, previous literature provides only an aggregate estimate that applies to all lateral sinus lift techniques irrespective of different bone graft materials. Therefore, if an exactly identical effect is applied to all comparators, this will not result in any alteration in the effectiveness differential between various lateral techniques of sinus-floor elevation. In the end, such parallel shifts in effectiveness will have no impact on considerations of cost-effectiveness and can, thus, be considered irrelevant within the framework of health economic modelling (Drummond et al. 2005).

In addition to base case scenarios A and B, we consider a further clinically relevant aspect: we simulate situations in which only a limited amount of autogenous bone is available. This means that bone grafting requires at least the partial use of allogenous bone. Resting on the same assumptions as in base case scenarios A and B, alternative scenarios A and B additionally involve that only half of the required bone grafting material can be yielded with autogenous bone.

Costs

The costs that arise from sinus-floor elevation include the cost of materials (anaesthesia, surgical instruments, bone grafts, membranes, stitching materials, implants, and restorations attached to the latter), and reimbursement of dentist and staff. Except for substitutive bone grafts, membranes, implants, and fabrication of crowns (which are charged according to the manufacturers' prices), accounting of material costs as well as reimbursement of dental professionals correspond to fees per item as listed in the Gebührenordnung für Zahnarzte (GOZ; see Bundesgesetzblatt 2001). The GOZ is uniformly valid throughout Germany and usually constitutes the medical fee schedule for privately insured patients. In the case of sinus-floor elevation, however, it also applies to publicly insured patients because the according surgical procedures are not covered by the German Public Health System. Specifically, the constituent costs of sinus lift treatment according to the GOZ are calculated on the basis of the following formula (Bundesgesetzblatt 2001):

$$\mathrm{Cost}_{\mathrm{GOZ}} = p_{\mathrm{GOZ}} \times \mu \times \tau,$$

where p_{GOZ} is the chargeable item points according to the GOZ; μ the monetary conversion factor (€5.62421 – cents per GOZ item point); and τ the treatment time factor, dependent on the complexity of the individual case.

Note that for cost calculations according to the GOZ, we follow the joint guideline of German professional associations for implantology (Streckbein 2006), which defines treatment items to be claimed during sinus lifting. Moreover, we rely on two frequently applied treatment time factors in order to model clinical cases associated with average ($r = 2.3$) and increased ($r = 3.5$) expenditure of treatment time (Bundesgesetzblatt 2001). In summary, Table 2a lists sinus lift costs as per the GOZ and dependent on time needed for treatment.

In addition, we make the following assumptions to enable precise accounting of costs:

- the amount of autogenous/substitutive bone graft that is required for lateral sinus lift techniques equals 4.0 g,
- a mix of autogenous and substitutive bone graft consists of 2.0 g substitutive bone graft and 2.0 g autogenous particulated bone,
- the costs of an implant, a membrane, and of substitutive bone graft correspond to averages as derived from 10 different manufacturers each (see Tables 2b–d), and
- implant loading takes place after an initial healing period after implant placement and with a single crown (expected costs inclusive abutment = €400).

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Table 2a. Costs of treatment procedures in sinus-floor elevation according to the GOZ

Procedure	Cost for average treatment time ($\tau = 2.3$) (€)	Cost for increased treatment time ($\tau = 3.5$) (€)
Maxillary anaesthesia	7.75	11.80
Internal sinus lift	62.08	94.47
Accessing the sinus maxillaris via a lateral window	54.56	83.02
Mobilization of the sinus membrane	92.24	140.35
Creation of a bone bed and bone condensation	67.02	101.99
Free bone transplantation	198.42	301.95
Extraction of autologous particulate bone	86.73	131.99
Implantation of autologous particulate bone	99.06	150.75
Placement of a membrane for bone regeneration	58.21	88.59
Padding with autologous/substitute bone graft	23.28	35.42
Preparation of bone cavity for implant insertion	62.10	94.50
Application of a drilling template	11.64	17.71
Implant insertion	62.10	94.50
Metric analysis and planning of implant insertion	69.85	106.30
Insertion of secondary implant parts	41.40	63.00
Full crown restoration on an implant	116.43	177.17
Provisional crown	34.94	53.17

Costs for average treatment times are calculated on the basis of a 2.3 treatment time factor, costs for increased treatment times are calculated on the basis of a 3.5 treatment time factor; sinus-lift costs according to the GOZ are VAT exempt.
GOZ, Gebührenordnung für Zahnarzte.

Table 2b. Implants included for the calculation of average costs

Implant type	Cost (€)
Dyna Helix®	235.56
Alphatech DUOTex®	177.31
Dentsply Friadent XiVE™ TG	218.96
Altatec SCREW-LINE™	183.26
Astra Tech OsseoSpeed™	251.09
Biomet 3i OSSEOTITE®	264.18
Keystone STAGE-1®	177.31
Nobel Biocare NobelReplace™ Tapered Groovy	296.31
Straumann® Standard Implant	238.64
Anthogyr Anthofit®	196.35
Average	223.90

Costs derived from Flohr (2009); VAT included for all monetary values.

Table 2c. Membranes included for the calculation of average costs

Membrane type	Cost (€)
BIOMET 3i OsseoGuard™	163.03
Geistlich Bio-Gide®	140.42
aap biomaterials SIC b-mem	113.05
ColBar OSSIX PLUS small	177.31
Hypro-Sorb ® F	130.90
Imtec BioSorb® Collagen Resorbable Membrane	113.05
Kensey Nash Epi-Guide®	124.95
BIOMATLINE 4BONE RCM	123.76
OSTEOPLANT ELITE®	190.40
GENTA-COLL® resorb-Foil	141.61
Average	141.85

Costs derived from Flohr (2009); VAT included for all monetary values.

Table 2d. Bone substitutes included for the calculation of average costs (2.0 g each)

Bone substitute type	Cost (€)
NuOss® Granulat Cancellous	235.62
Fortoss Resorb®	214.20
Straumann® BoneCeramic	307.02
BIO-GEN® Granulate	237.21
Calc-i-oss™	141.97
OsteoGraf ® N-700	213.01
Geistlich BioOss®Spongiose	280.84
Schütz ReBone	238.00
DOT BONIT matrix®	188.02
CEROS®	285.60
Average	234.14

Costs derived from Flohr (2009); VAT included for all monetary values.

Deciding on cost-effectiveness

These clinical and monetary considerations are incorporated into a decision tree as depicted in Fig. 1. Then, for any of the nine treatment options considered, we calculate the net benefit (Stinnett & Mullahy 1998) as follows:

$$\text{NB} = (\lambda \times B) - C,$$

where λ is the threshold value for willingness to pay (WTP) for an additional time unit of implant survival B (months), and C the costs for providing sinus-floor elevation and implant placement.

Accordingly, the optimum treatment strategy is the sinus lift option that yields the maximum net benefit in comparison with all the other options under consideration (Stinnett & Mullahy 1998). Note that WTP is a general concept in health economic evaluation for characterizing the maximum amount of money that an individual is willing to sacrifice to receive one incremental unit of a health benefit (Drummond et al. 2005).

To incorporate uncertainties regarding implant survival, a probabilistic sensitivity analysis (Weinstein et al. 2003) is implemented that assigns a triangular distribution function to each health outcome. The upper and lower bounds equate to the 95% confidence intervals and the most likely point within each distribution is defined by the point estimate for implant survival. A Monte-Carlo simulation (Doubilet et al. 1985) with 50,000 repetitions is then conducted to identify the probabilities with which different treatment strategies yield the maximum net benefit criterion.

All data modelling and probabilistic sensitivity analysis were conducted using the software package TreeAge (TreeAge Software Inc., Williamstown, MA, USA). Finally, it should be noted that we follow the guidelines of the German Institute for Quality and Efficiency in Health Care (IQWiG 2009) and apply an annual discount rate of 3% for both costs and health outcomes.

Results

Figure 2 shows the cost-effectiveness plane. It assigns each of the nine treat-

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ment options an effectiveness value on the *x*-axis and a cost value on the *y*-axis. In general, the more to the right and the more to the bottom of the plane a strategy is positioned, the higher its cost-effectiveness will be. The graph emphasizes that the transalveolar sinus lift approach dominates lateral approaches that do not utilize a resorbable membrane, in accordance with clinically better performance and less cost. Moreover, the lateral sinus lift approach with an autogenous particulate bone graft and a resorbable membrane is superior to other lateral techniques that utilize a membrane, because of greater effectiveness and lower cost. Although Fig. 2 clearly identifies the lateral sinus lift approach with autogenous particulate bone and a resorbable membrane as the most effective therapeutic option, so far, it is not clear how cost considerations affect the optimum treatment decision in different clinical scenarios.

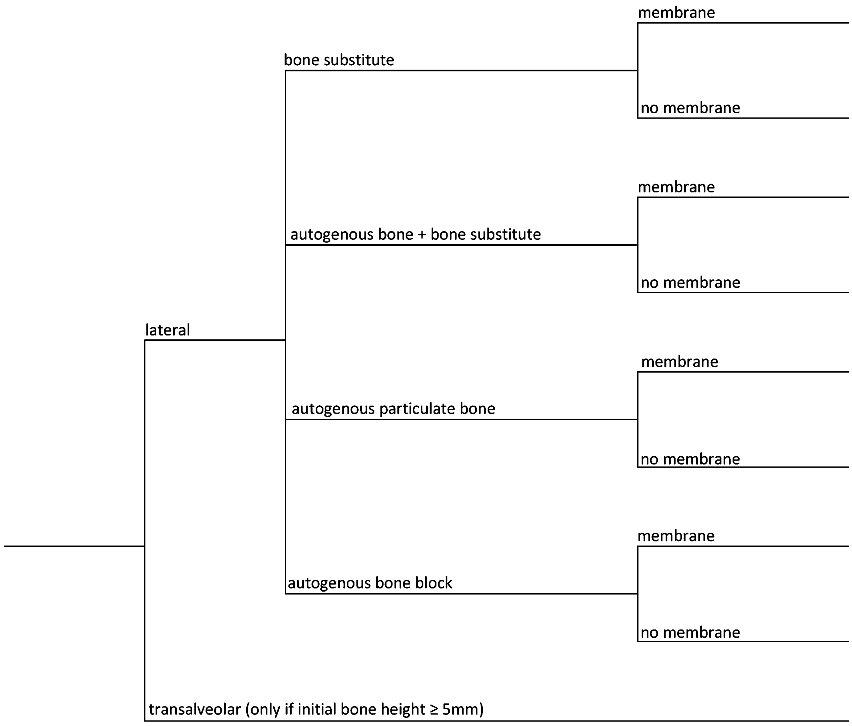

Fig. 1. Stylized decision tree for sinus-floor elevation. *Note*: If bone height $\geqslant$5 mm: implant placement simultaneous with sinus-floor elevation (one-stage approach); if bone height $<$5 mm: delayed implant placement (two-stage approach), transalveolar approach not applicable.

Base case scenario A

Figure 3 plots the cost-effectiveness acceptability frontier for base case scenario A (bone height $>$5 mm, no restrictions in the amount of autogenous bone) when costs correspond to the average treatment time and the time perspective is 3 years. More precisely, it identifies the treatment strategies along the WTP axis that fulfil the maximum net benefit criterion. Additionally, the graph assigns the probability that each of these treatment options is cost-effective (within a 3-year time period). Therefore, Fig. 3 shows that:

- the transalveolar technique is the most cost-effective therapeutic alternative for WTP values below €195 per additional month of implant survival, and
- the lateral technique with particulate autogenous bone and membrane is the most cost-effective therapeutic alternative for WTP values above €195 per additional month of implant survival.

Below the switch point at a WTP of €195 the transalveolar technique becomes increasingly likely to be the most cost-effective technique within a 3-year period. In contrast, i.e. with increasing WTP values above €195 per additional month of implant survival, the lateral technique with particulate autogenous bone and membrane becomes increasingly likely to yield the maximum net benefit. The finding that at the strategy switch point (WTP = €195) both therapeutic alterna-

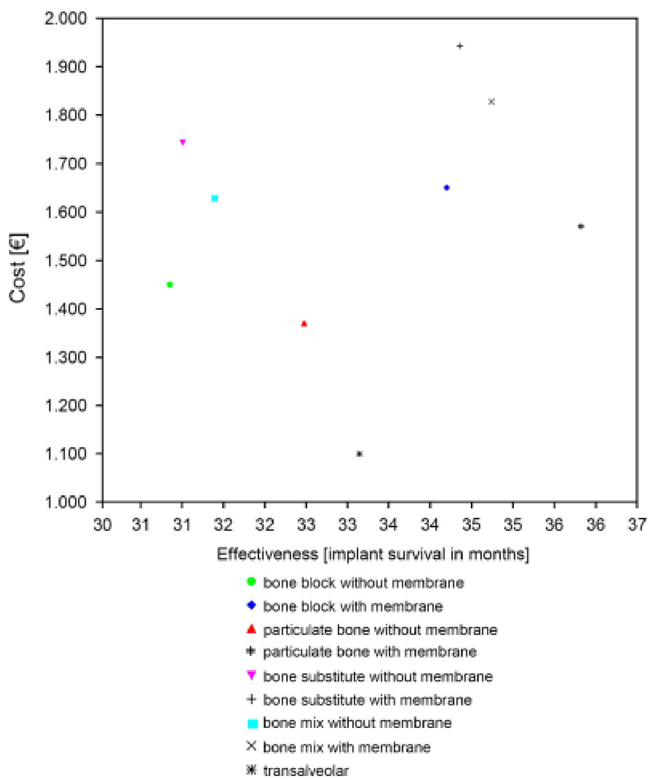

Fig. 2. The cost-effectiveness plane.

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tives have an approximately 50% probability of being cost-effective also indicates that, mostly, these two treatment strategies compete to be the optimum decision. Furthermore, as shown in Table 3a, consideration of costs due to increased treatment time and including a long-term perspective by extrapolating outcomes to 15 years after sinus lifting confirms that these two strategies are the only relevant strategies in terms of maximum net benefit considerations. However, the WTP thresholds at which the optimum strategy change are found at altered levels: within a 3-year perspective and in a setting of increased time needed for treatment, the strategy switch point lies at €264 per additional month of implant survival; within a 15-year perspective, the strategy switch points are found at €580 (average treatment time) and €791 (increased treatment time) per additional year of implant survival.

Base case scenario B

Figure 4 plots the cost-effectiveness acceptability frontier for base case scenario B (bone height <5 mm, no restrictions in the amount of autogenous bone) when costs correspond to the average treatment time and the time perspective is 3 years. It identifies that:

- the lateral technique with particulate autogenous bone but without membrane is the most cost-effective therapeutic alternative for WTP values below €66 per additional month of implant survival, and
- the lateral technique with particulate autogenous bone and membrane is the most cost-effective therapeutic alternative for WTP values above €66 per additional month of implant survival.

As shown in Table 3b, consideration of costs due to increased treatment time and inclusion of a long-term perspective (extrapolation of outcomes to 15 years after sinus lifting) confirm that these two strategies remain the only relevant strategies in terms of the maximum net benefit considerations. However, the WTP thresholds at which the optimum strategy change are, again, found at altered levels: within a 3-year perspective and in a setting of increased time needed for treatment, the strategy switch point lies at €78 per additional month of implant survival; within a 15-year perspective, the strategy switch points are found at €186 (average treatment time) and €214 (increased treatment time) per additional year of implant survival.

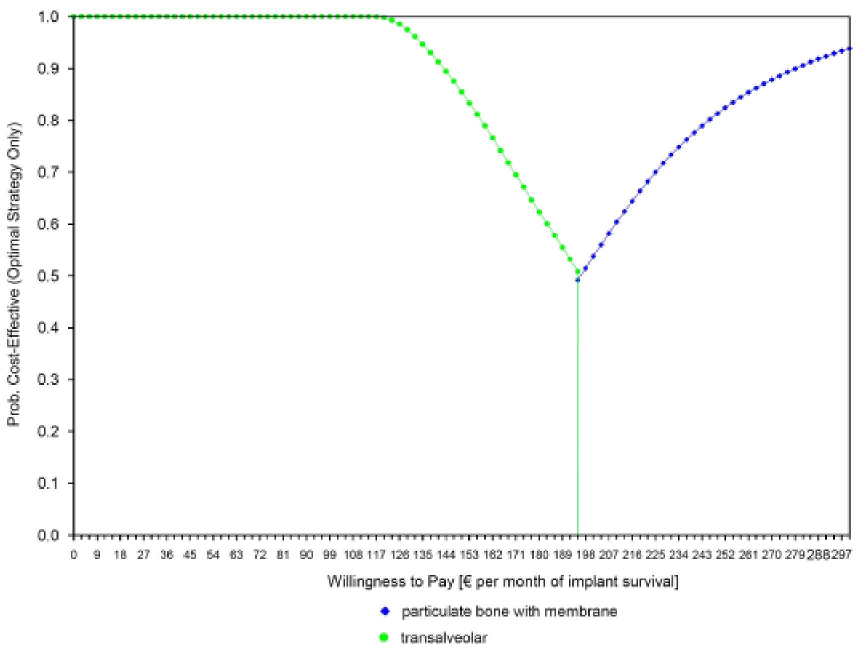

Fig. 3. Cost-effectiveness acceptability frontier for base case scenario A (bone height $\geqslant 5$ mm, no restrictions in the amount of autogenous bone). *Note*: Three-year time perspective; costs correspond to the average treatment time.

Alternative scenario A

Figure 5 plots the cost-effectiveness acceptability frontier for alternative scenario A (bone height >5 mm, restricted amount of autogenous bone) when costs correspond to the average treatment time and the time perspective is 3 years. It shows that:

- the transalveolar technique is the most cost-effective therapeutic alternative for WTP values below €500 per additional month of implant survival, and
- the lateral technique with a mix of autogenous/substitutive bone and membrane is the most cost-effective therapeutic alternative for WTP values above €500 per additional month of implant survival.

Table 3a. Cost-efficient treatment strategies for base case scenario A (bone height >5 mm, no restrictions in the amount of autogenous bone)

	3-year perspective		15-year perspective*	
	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)
WTP < threshold	Transalveolar		Transalveolar	
Threshold WTP	195 (€ per implant month)	264 (€ per implant month)	580 (€ per implant year)	791 (€ per implant year)
WTP > threshold	Autogenous particulate bone and membrane		Autogenous particulate bone and membrane	

*Extrapolation.

WTP, decision maker's willingness to pay; the average (increased) treatment time corresponds to a 2.3 (3.5) treatment time factor for the calculation of costs according to the GOZ; GOZ, Gebührenordnung für Zahnarzte.

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As shown in Table 3c, consideration of costs due to increased treatment time and inclusion of a long-term perspective (extrapolation of outcomes to 15 years after sinus lifting) verify that these two strategies remain the only relevant strategies in terms of the maximum net benefit considerations. Yet, the WTP thresholds at which the optimum strategy change are, once more, found at altered levels: within a 3-year perspective and in a setting of increased time needed for treatment, the strategy switch point lies at €630 per additional month of implant survival; within a 15-year perspective, the strategy switch points are found at €1571 (average treatment time) and €1967 (increased treatment time) per additional year of implant survival.

Alternative scenario B

Figure 6 plots the cost-effectiveness acceptability frontier for base case scenario B (bone height <5 mm, restricted amount of autogenous bone) when costs correspond to the average treatment time and the time perspective is 3 years. It identifies that:

- the lateral technique with a mix of autogenous/substitutive bone but without membrane is the most cost-effective therapeutic alternative for WTP values below €66 per additional month of implant survival, and
- the lateral technique with a mix of autogenous/substitutive bone and membrane is the most cost-effective therapeutic alternative for WTP values above €66 per additional month of implant survival.

As shown in Table 3d and similar to the other clinical scenarios, the consideration of costs due to increased treatment time and inclusion of a long-term perspective (extrapolation of outcomes to 15 years after sinus lifting) confirms that the above two strategies remain the only relevant strategies in terms of the maximum net benefit considerations. The WTP thresholds at which the optimum strategy change are found at altered levels, though: within a 3-year perspective and in a setting of increased time needed for treatment, the strategy switch point lies at €78 per additional month of implant survival; within a 15-year perspective, the strategy switch points are found at €186 (average treatment time) and €214 (increased treatment time) per additional year of implant survival.

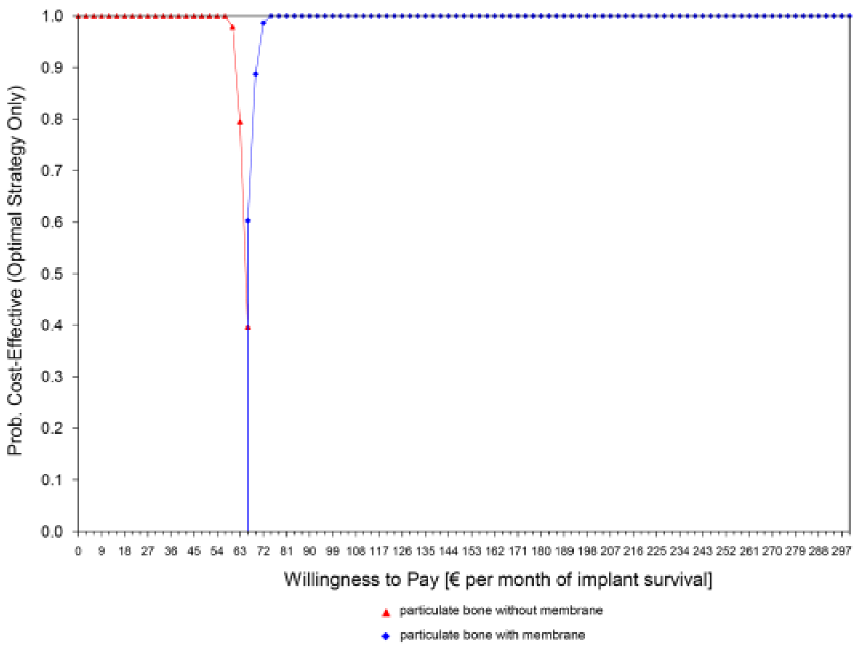

Fig. 4. Cost-effectiveness acceptability frontier for base case scenario B (bone height <5 mm, no restrictions in the amount of autogenous bone). *Note*: Three-year time perspective; costs correspond to the average treatment time.

Discussion

On the basis of currently available evidence and current market prices, this paper identifies the most cost-effective sinus lift approach as follows: when the initial bone height at implant site is above 5 mm, the transalveolar technique is generally advisable if the available budget is restricted to <€195 (average expenditure of treatment time) or <€264 (increased expenditure of treatment time) per additional month of implant survival within a 3-year time period. If, however, more than these values can be spent, the decision regarding the optimum (most cost-effective) sinus lift approach also depends on the amount of autogenous bone available: when the quantity of autogenous bone is not limited, the most cost-effective approach is to perform a lateral operation with autogenous particulate bone

Table 3b. Cost-efficient treatment strategies for base case scenario B (bone height <5 mm, no restrictions in the amount of autogenous bone)

	3-year perspective		15-year perspective*	
	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)
WTP < threshold	Autogenous particulate	bone, no membrane	Autogenous particulate	bone, no membrane
Threshold WTP	66 (€ per implant month)	78 (€ per implant month)	186 (€ per implant year)	214 (€ per implant year)
WTP > threshold	Autogenous particulate	bone and membrane	Autogenous particulate	bone and membrane

*Extrapolation.

WTP, decision maker's willingness to pay; average (increased) treatment time corresponds to a 2.3 (3.5) treatment time factor for calculation of costs according to the GOZ; GOZ, Gebührenordnung für Zahnarzte.

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and a resorbable membrane. When the quantity of autogenous bone can provide up to half of the required volume of grafting material only, however, the range in which the transalveolar technique is the optimum choice becomes wider. Only if payment of >€500 (average expenditure of treatment time) or >€630 (increased expenditure of treatment time) per additional implant month is accepted is the optimum choice a lateral approach that combines a mixture of autogenous and substitute bone with a resorbable membrane. Alternatively, a decision maker may favour a long-term perspective, as implemented by extrapolation of outcomes to 15 years after sinus lifting. Within the methodological limitations of such a prediction, this translates into a WTP threshold of €580 (average expenditure of treatment time) or €791 (increased expenditure of treatment time) per additional year of implant survival, below which the transalveolar approach and above which the lateral approach with autogenous bone and membrane are most cost-effective. When the amount of autogenous bone is limited, however, the decision is restricted to a WTP threshold of €1571 (average expenditure of treatment time) or €1967 (increased expenditure of treatment time) per additional year of implant survival under consideration of the transalveolar technique and the lateral sinus-floor elevation approach in combination with a mixture of autogenous/substitute bone plus membrane.

When the initial bone height at implant site is below 5 mm, lateral sinus lift techniques are advisable that use autogenous particulate bone or, if the amount of autogenous bone is limited, a mix of autogenous/substitute bone graft. In both cases, restrictions in monetary resources only affect whether additional application of a resorbable membrane is recommendable from a cost-effectiveness perspective. Within a 3-year time period, the use of a membrane is only optimal if payment of >€66 (average expenditure of treatment time) or >€78 (increased expenditure of treatment time) can be spent per additional month of implant survival. Within a long-term perspective (extrapolation of outcomes to 15 years after sinus lifting), the use of a membrane can only be considered cost-efficient if the decision maker is willing to pay >€186 (average expenditure of treatment time) or €214 (increased expenditure of treatment time) per additional implant year.

To some extent, the findings of our study may be limited by lack of more detailed evidence regarding outcomes after sinus lifting.

First, the reliable time period of health outcomes is restricted to only 3 years; a longer follow-up period after sinus lifting would provide better information about implant survival after sinus-floor elevation, specifically with respect to different bone grafting materials. Although methodologically straightforward, the tailored extrapolation we conducted may be regarded as tentative only. Nevertheless, the results of the corresponding 15-year prediction substantiate the relevance of a long-term perspective.

Second, we made the assumption that not utilizing a membrane during the lateral approach would always result in the same negative effect on implant survival, irrespective of the surgical procedure used. Although we do not generally question the positive effect of membrane application, we expect some variation in membrane effectiveness, depending on the underlying surgical approach; the exact extent of this is still to be determined. Moreover, we modelled the ''no membrane effect'' relative to (bone graft-specific) estimates of implant survival drawn from pooled

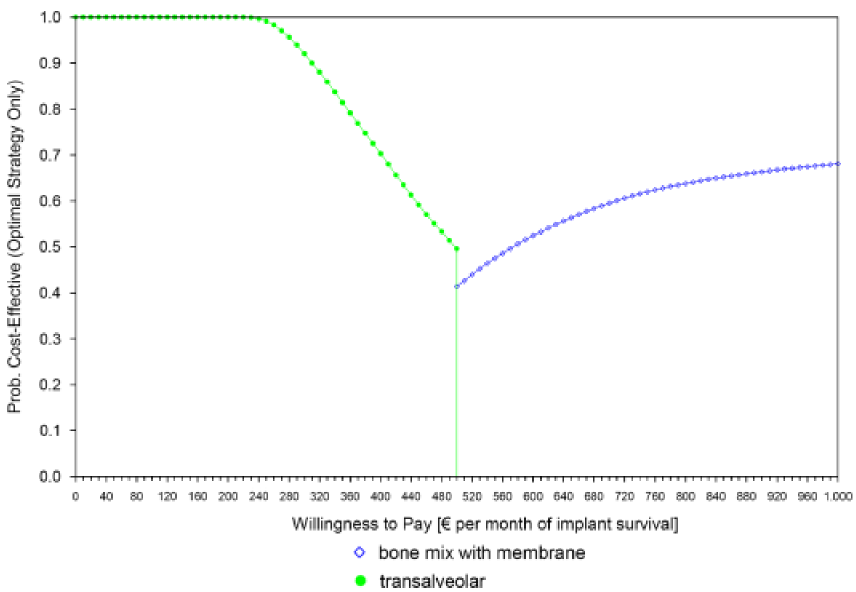

Fig. 5. Cost-effectiveness acceptability frontier for alternative scenario A (bone height ⩾5 mm, restricted amount of autogenous bone). *Note*: Three-year time perspective; costs correspond to the average treatment time.

Table 3c. Cost-efficient treatment strategies for alternative scenario A (bone height >5 mm, restricted amount of autogenous bone)

	3-year perspective		15-year perspective*	
	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)
WTP < threshold	Transalveolar		Transalveolar	
Threshold WTP	500 (€ per implant month)	630 (€ per implant month)	1571 (€ per implant year)	1967 (€ per implant year)
WTP > threshold	Bone mix and membrane		Bone mix and membrane	

*Extrapolation.

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observations of lateral sinus lifting with/without membrane application (Pjetursson et al. 2008). If the corresponding bias has any effect, it will lead to underestimation of the effectiveness of lateral sinus lift approaches within our model. It may not, however, invalidate the general inferences from our results.

Third, in this paper, we only considered the objective measure of implant survival as a clinical endpoint. Another objective of clinical decision making, however, is usually to take into account the subjective perception of treatment by the patient (Kaplan et al. 1976, Dolan et al. 1996, Bowling 1997).

Future research that seeks to identify more detailed information on the long-term treatment effectiveness of sinus lift techniques is therefore encouraged. For instance, patient-centred outcomes in response to oral surgery could be assessed by means of OHIP-14 (McGrath et al. 2003). In terms of the generalizability of our findings, one concern may be that the results of this paper would only be valid for Germany. Note, however, that the clinical evidence we rely on is not restricted to any single geographic setting. Furthermore, the very exact costs we incorporate into our decision analytical model can, of course, only be regarded as fully reliable for the specific scenario we assume. The cost differential between the treatment strategies in our model mainly results from the prices of bone grafting materials and resorbable membranes, however. Even though the corresponding market prices may vary across countries, the relative prices can be expected to correspond with the cost scheme we use in our model. Therefore we expect quite broad generalizability of our findings, if not necessarily to the last decimal place.

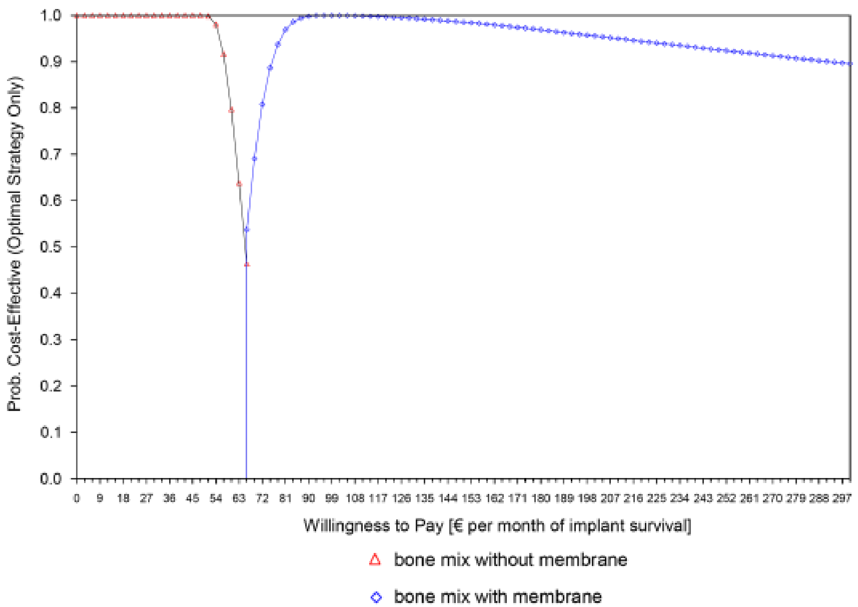

Fig. 6. Cost-effectiveness acceptability frontier for alternative scenario B (bone height <5 mm, restricted amount of autogenous bone). *Note*: Three-year time perspective; costs correspond to the average treatment time.

Overall, this study adds a new perspective to the current literature on sinus-floor elevation. It is increasingly being recognized that cost-effectiveness considerations are an important aspect of decision making in dentistry (Pennington et al. 2009a, Braegger 2005). Specifically, the Consensus report of the Sixth European Workshop on Periodontology has emphasized that periodontal intervention (Sanz & Teughels 2008) as well as sinus lifting (Tonetti & Hämmerle 2008) should be evaluated from an economic perspective. In this sense, two previous papers have investigated economic aspects of supportive periodontal treatment (Pretzl et al. 2009, Gaunt et al. 2008). Another recent paper (Pennington et al. 2009b) has established a Markov model for comparing the lifetime cost-effectiveness of endodontic and implant approaches for the treatment of an irreversibly pulpitic maxillary incisor. In this context, this paper may provide complementary information for the treatment of a compromised molar in the maxilla when vertical bone height is reduced.

In conclusion, the results in this paper lead to three recommendations for a clinician. When there are no financial restrictions on a sinus lift, the optimum treatment strategy is (1) the lateral approach with autogenous particulate bone and a resorbable membrane. When, however, monetary resources for sinus-floor elevation are scarce, the decision depends on the initial bone height at the implant site. In cases where bone height is sufficiently high, the most cost-effective option is (2) the transalveolar technique without bone grafting. In cases where bone height is comparably low, it is most cost-effective to rely on (3) a lateral approach with as much autogenous particulate bone as available. Thereby, clinicians should only refrain from membrane application if monetary resources are markedly scarce.

Table 3d. Cost-efficient treatment strategies for alternative scenario B (bone height <5 mm, restricted amount of autogenous bone)

	3-year perspective		15-year perspective*	
	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)	average treatment time ($\tau = 2.3$)	increased treatment time ($\tau = 3.5$)
WTP < threshold	Bone mix, no membrane		Bone mix, no membrane	
Threshold WTP	66 (€ per implant month)	78 (€ per implant month)	186 (€ per implant year)	214 (€ per implant year)
WTP > threshold	Bone mix and membrane		Bone mix and membrane	

*Extrapolation.

WTP, decision maker's willingness to pay; average (increased) treatment time corresponds to a 2.3 (3.5) treatment time factor for calculation of costs according to the GOZ; GOZ, Gebührenordnung für Zahnarzte.

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References

Bland, J. M. (2000) *An Introduction to Medical Statistics*, 3rd edition. Oxford: Oxford University Press.

Bowling, A. (1997) *Measuring Health: A Review of Quality of Life and Measurement Scales*. Milton Keynes, UK: Open University Press.

Braegger, U. (2005) Cost-benefit, cost-effectiveness and cost-utility analyses of periodontitis prevention. *Journal of Clinical Periodontology* **32** (Suppl. 6), 301–313.

Bundesgesetzblatt. (2001) *Gebührenordnung für Zaharzte*. Berlin: German Federal Ministry of Justice.

Buxton, M. J., Drummond, M. F., Van lout, B. A., Prince, R. L., Sheldon, T. A., Szucs, T. & Vray, M. (1997) Modelling in economic evaluation: an unavoidable fact of life. *Health Economics* **6**, 217–227.

Chao, Y.-L., Chen, H.-H., Mei, C.-C., Tu, Y.-K. & Lu, H.-K. (2010) Meta-regression analysis of the initial bone height for predicting implant survival rates of two sinus elevation procedures. *Journal of Clinical Periodontology* **37**, 456–465.

Claxton, K., Lacey, L. F. & Walker, S. G. (2000) Selecting treatments: a decision theoretic approach. *Journal of the Royal Statistical Society* **163**, 211–225.

Dolan, P., Gudex, C., Kind, P. & Williams, A. (1996) Valuing health states: a comparison of methods. *Journal of Health Economics* **2**, 209–232.

Doubilet, P., Begg, C. B., Weinstein, M. C., Braun, P. & McNeil, B. J. (1985) Probabilistic sensitivity analysis using Monte Carlo simulation. A practical approach. *Medical Decision Making* **5**, 157–177.

Drummond, M. F., Sculpher, M. J., Torrance, G. W., OBrien, B. J. & Stoddart, G. L. (2005) *Methods for the Economic Evaluation of Health Care Programmes*. Oxford: Oxford University Press.

Emmerich, D., Att, W. & Stappert, C. (2005) Sinus floor elevation using osteotomes: a systematic review and meta-analysis. *Journal of Periodontology* **76**, 1237–1251.

Fleming, T. R. & DeMets, D. L. (1996) Surrogate end points in clinical trials: are we being misled?. *Annals of Internal Medicine* **125**, 605–613.

Flohr, M. (2009) *DENTAL KOMPAKT 2009*. Balingen: Spitta Verlag.

Fugazzotto, P. A. (1994) Maxillary sinus grafting with and without simultaneous implant placement: technical considerations and case reports. *The International Journal of Periodontics Restorative Dentistry* **14**, 544–551.

Gaunt, F., Devine, M., Pennington, M., Vernazza, C., Gwynnett, E., Steen, N. & Heasman, P. (2008) The cost-effectiveness of supportive periodontal care for patients with chronic periodontitis. *Journal of Clinical Periodontology* **35**, 67–82.

Handschel, J., Simonowska, M., Naujoks, C., Depprich, R. A., Ommerborn, M. A., Meyer, U. & Kuebler, N. R. (2009) A histomorphometric meta-analysis of sinus elevation with various grafting materials. *Head and Face Medicine* **5**, 1–10.

Hirsch, J. M. & Ericsson, I. (1991) Maxillary sinus augmentation using mandibular bone grafts and simultaneous installation of implants. A surgical technique. *Clinical Oral Implants Research* **2**, 91–96.

Institute for Quality and Efficiency in Health Care (IQWiG). (2009) Allgemeine Methoden zur Bewertung von Verhaltnissen zwischen Nutzen und Kosten. Available at http://www.iqwig.de (accessed 23 November 2009).

Kaplan, R. M., Bush, J. W. & Berry, C. C. (1976) Health status: types of validity and the index of well-being. *Health Services Research* **11**, 478–507.

Mazor, Z., Peleg, M., Garg, A. K. & Chaushu, G. (2000) The use of hydroxyapatite bone cement for sinus floor augmentation with simultaneous implant placement in the atrophic maxilla. A report of 10 cases. *Journal of Periodontology* **71**, 1187–1194.

McGrath, C., Comfort, M. B., Lo, E. C. M. & Luo, Y. (2003) Patient-centred outcome measures in oral surgery: validity and sensitivity. *British Journal of Oral and Maxillofacial Surgery* **41**, 43–47.

Misch, C. E. (1987) Maxillary sinus augmentation for endosteal implants. Organized alternative treatment plans. *International Journal of Oral Implantology* **4**, 49–58.

Nkenke, E., Schlegel, A., Schultze-Mosgau, S., Neukam, F. W. & Wiltfang, J. (2002) The endoscopically controlled osteotome sinus floor elevation: a preliminary prospective study. *The International Journal of Oral and Maxillofacial Implants* **17**, 557–566.

Peleg, M., Mazor, Z. & Garg, A. K. (1999) Augmentation grafting of the maxillary sinus and simultaneous implant placement in patients with 3 to 5mm of residual alveolar bone height. *The International Journal of Oral and Maxillofacial Implants* **14**, 549–556.

Pennington, M., Vernazza, C. R., Shackley, P., Armstrong, N. T., Whitworth, J. M. & Steele, J. G. (2009b) Evaluation of the cost-effectiveness of root canal treatment using conventional approaches versus replacement with an implant. *International Endodontic Journal* **42**, 874–883.

Pennington, M. W., Vernazza, C. R. & Heasman, P. (2009a) Making the leap from cost analysis to cost-effectiveness. *Journal of Clinical Periodontology* **36**, 667–668.

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. Part I – Lateral technique. *Journal of Clinical Periodontology* **35** (Suppl. 8), 216–240.

Prentice, R. L. (1989) Surrogate endpoints in clinical trials: definition and operational criteria. *Statistics in Medicine* **8**, 431–440.

Pretzl, B., Wiedemann, D., Cosgarea, R., Kaltschmitt, J., Kim, T. S., Staehle, H. J. & Eickholz, P. (2009) Effort and costs of tooth preservation in supportive periodontal treatment in a German population. *Journal of Clinical Periodontology* **36**, 669–676.

Rosen, P. S., Summers, R., Mellado, J. R., Salkin, L. M., Shanaman, R. H., Marks, M. H. & Fugazzotto, P. A. (1999) The bone-added osteotome sinus floor elevation technique: multicenter retrospective report of consecutively treated patients. *The International Journal of Oral and Maxillofacial Implant* **14**, 853–858.

Sanz, M. & Teughels, W. (2008) Innovations in non-surgical periodontal therapy: Consensus Report of the Sixth European Workshop on Periodontology. *Journal of Clinical Periodontology* **35**, 3–7.

Smiler, D. G., Johnson, P. W., Lozada, J. L., Misch, C., Rosenlicht, J. L., Tatum, O. H. Jr. & Wagner, J. R. (1992) Sinus lift grafts and endosseous implants. Treatment of the atrophic posterior maxilla. *Dental Clinics of North America* **36**, 151–186.

Stinnett, A. A. & Mullahy, J. (1998) Net health benefits: a new framework for the analysis of uncertainty in cost-effectiveness analysis. *Medical Decision Making* **18**, S68–S80.

Streckbein, R. (2006) Gemeinsame Erklärung zur gebührenrechtlichen Bewertung neuerer Ver- fahren in der Implantologie der Deutschen Gesellschaft für Implantologie im Zahn-, Mund-, und Kieferbereich e. V., der Deutschen Gesellschaft für zahnaerztliche Implantologie e. V., der Deutschen Gesellschaft für Mund-, Kiefer- und Gesichtschirurgie e. V., und des Berufsverban- des Deutscher Oralchirurgen e. V.

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 2008* **35** (Suppl. 8), 241–254.

ten Bruggenkate, C. M. & van den Bergh, J. P. (1998) Maxillary sinus floor elevation: a valuable pre-prosthetic procedure. *Periodontology 2000* **17**, 176–182.

Toffler, M. (2004a) Osteotome-mediated sinus floor elevation: a clinical report. *The International Journal of Oral and Maxillofacial Implants* **19**, 266–273.

Toffler, M. (2004b) Minimally invasive sinus floor elevation procedures for simultaneous and staged implant placement. *New York State Dental Journal* **70**, 38–44.

Tonetti, M. S. & Hämmerle, C. H. F. (2008) Advances in bone augmentation to enable dental implant placement: Consensus Report of the Sixth European Workshop on Periodontology. *Journal of Clinical Periodontology* **35** (Suppl. 8), 168–172.

van den Bergh, J. M. P., ten Bruggenkate, C. M., Krekeler, G. & Tuinzing, D. B. (1998) Sinus floor elevation and grafting with autogenous bone from the iliac crest. *Clinical Oral Implants Research* **9**, 429–435.

Weinstein, M. C., O'Brien, B., Hornberger, J., Jackson, J., Johannesson, M., McCabe, C. & Luce, B. R. (2003) Principles of good

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practice for decision analytic modeling in health-care evaluation: report of the ISPOR task force on good research practices-modeling studies. *Value in Health* **6**, 9–17.

Weyant, R. J. & Burt, B. A. (1993) An assessment of survival rates and within patient clustering of failures for endosseous oral implants. *Journal of Dental Research* **72**, 2–8.

Woo, I. & Le, B. T. (2004) Maxillary sinus floor elevation: review of anatomy and two techniques. *Implant Dentistry* **13**, 28–32.

Zitzmann, N. U. & Scharer, P. (1998) Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **85**, 8–17.

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Clinical Relevance

Scientific rationale for the study: Previous clinical evidence suggests that lateral sinus lift techniques with autogenous bone grafting yield favourable outcomes in comparison with other sinus lift approaches. However, monetary resources for treatment can be limited and may restrict therapeutic possibilities. The purpose of this study was to identify the most cost-effective sinus lift technique.

Principal findings: Decision analytical modelling revealed that the trans-alveolar sinus lift technique is the most cost-effective strategy when treatment budgets are limited. Only if relatively high costs can be afforded or initial bone height is substantially reduced are lateral approaches preferable.

Practical implications: When treatment costs are important, the trans-alveolar sinus lift approach may form the mainstay of therapy.

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