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REVIEW ARTICLE

A narrative review of the survival of dental implants placed simultaneously with lateral sinus floor elevations without the use of graft materials

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Key words:
bone regeneration, dental implant, sinus floor elevation, sinus lift

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Abstract

This review aims to critically appraise the available evidence for the survival of implants placed simultaneously with sinus floor elevation without the use of grafting materials. The atrophic maxillary sinus may be restored with implants using a variety methods and adjunctive grafting techniques. The placement of implants in the atrophic maxillary sinus with and without bone grafting was reviewed in a systematic manner by considering the evidence presented in clinical studies. The initial search yielded 983 titles. Following title-based, abstract-based and full-text evaluation 12 studies were identified, reporting on 1353 implants. Analysis identified a 98.38% survival rate at the point of uncovering. A further 0.3% of remaining implants were lost after 12 months and another 0.01% after 24 months. Beyond this point there were no further reported implant failures. Data were comparable for both grafted and ungrafted sinuses, with implants in ungrafted sinuses appearing to have a marginally higher success rate (98.11% vs. 97.87%).This review of implant data studies confirms that placing dental implants into maxillary sinuses with a graftless approach yields comparable implant survival to those cases that are grafted. This suggests that there is scope to simplify treatment protocols, decrease the risk of infection while maintaining treatment success and increase patient acceptance of sinus lift procedures.

Introduction

Changing patient expectations are driving the increasing requirement for the rehabilitation of the atrophic posterior maxilla with dental implants. Physiological changes that occur following the extraction of teeth often render residual bone insufficient for the placement of dental implants of a conventional length[1]. This has led to the development of transcrestal[2] and lateral approach sinus lifts[3,4], and/or the use of short implants[3], with success. Numerous materials have been utilised to support the Schneiderian membrane once elevated, ranging from autogenous block grafts to particulate xenografts[5]. It was noted incidentally that the creation of a void below the Schneiderian membrane could lead to spontaneous bone formation[6], encouraging clinicians to develop techniques where the apices of implants alone are used to support the elevated membrane to allow the formation of a blood clot that then differentiates into mature bone[7]. This has several potential advantages including improved patient acceptance with reduced use of graft material, the reduced need for the introduction of foreign body grafting materials into the sinus which may reduce the risk of infection, reduced cost and treatment time. There is, however, limited documentation available for simultaneous implant placement and sinus floor elevation via a lateral approach. The aim of this narrative review is therefore to summarise and critically appraise the clinical evidence for implants placed simultaneously into elevated

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maxillary sinuses both with and without the use of augmentation materials.

Materials and methods

Although a narrative review, a thorough research strategy was generated following the Cochrane Handbook for Systematic Reviews of Interventions. In order to narrow the context of the review, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement was used as adapted from Liberati *et al.*[8] and summarised in Figure 1. The focus rested on clinically objective outcomes such as radiographic bone levels and implant loss and prioritised randomised controlled studies. The clinical questions were identified using a PICOS (population, intervention, comparisons, outcomes, study design) strategy[9]. While the synthesis of choice would be a meta-analysis of individual participant level information from each of the included studies, such an analysis is unable take clustering of data into account[10]. Due to the limited quantity of data available around this subject area it was necessary to use cohort studies as well as RCTs as the source of evidence for this review. The heterogeneity of source data deem a narrative review appropriate.

Population

Human subjects or patients.

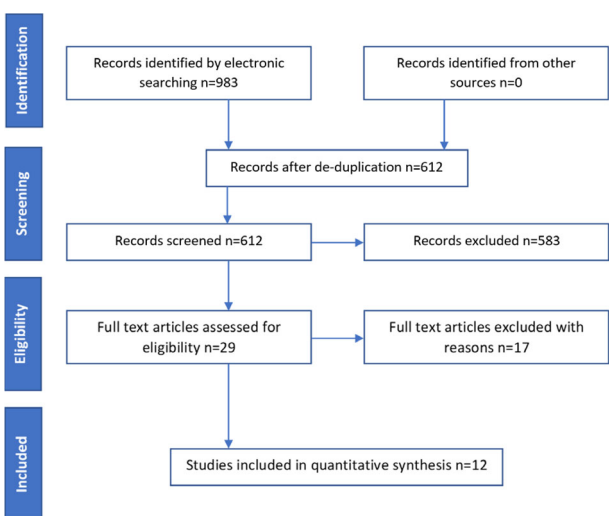

Figure 1 Flow diagram demonstrating study selection (adapted from[8]).

Intervention

Dental implants simultaneously placed in maxillary sinuses with floor elevation via a lateral approach both with and without graft material.

Outcome measure

Implant survival rate.

Study design
Randomised control trials, cohort studies, case–control and case series.

Search strategy

The assessment of the available literature related to a research question can be challenging with the emphasis here being placed upon optimising the quality of search results returned while minimising the number. An electronic search limited to the dental literature from human subjects in the English language between the dates 1 January 1995 and 31 December 2018 was performed using combinations of:

('maxillary sinus' OR 'sinus') AND ('lift' OR 'floor elevation' OR 'elevation' OR 'augmentation' OR 'lateral') AND ('simultaneous' OR 'immediate'))

=truncated search term

using MEDLINE, EMBASE and the Cochrane Oral Health Group's Trials Register and the Cochrane Central Register of Controlled Trials (CENTRAL).

Selection criteria

This review identified randomised controlled trials, case–control and cohort studies as well as case series that assessed implant survival after simultaneous implant placement and sinus floor elevation via a lateral approach, with or without augmentation materials. The following inclusion criteria were used:

- Studies reporting sinus floor elevation
- Minimum 12-month follow-up period after loading
- Studies reporting mean residual bone height equal and less than 6mm
- Studies reporting on implant survival rates
- Studies including a minimum of 10 patients
- Studies with clearly defined survival or success criteria

Studies with the following criteria were excluded:

- Unsuitable study design

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• Studies with less than 12 months follow-up in function
• No information on residual bone height
• Majority of implants placed in sites with residual bone height greater than 6mm
• Combination of grafting techniques used
• Multiple publications on the same patient group (most relevant study selected, data used only once)

Screening process

Both searching and screening were conducted by one of the authors (PJK), commencing with the assessment of the titles and abstracts. Full texts were sourced for review and inclusion and exclusion criteria applied.

Data extraction

Data were extracted from the included studies on: study design, patient numbers, follow-up period, treatment setting, residual bone height, surgical procedural techniques, type of graft (where grafted), pre- and post-operative care, implant characteristics, implant survival rate.

For the purposes of this study an implant was defined as surviving if it remains in situ at the point of data recording. Failure was defined as the point at which the implant was lost or removed, for whatever reason.

Assessment of the risk of bias and quality

The risk of bias and quality of studies was assessed in accordance with Critical Appraisal Skills Programme (CASP)[11] checklists as this allows the assessment of numerous different study designs within one relatively comparable framework. Each study was then assessed on the basis of the following seven relevant domains: confounding bias, selection bias, classification bias, deviation from intended intervention bias, missing data bias, outcome bias, reporting bias. These factors are then reported as being at low, unclear or high risk of bias.

Statistical analysis

Due to the heterogeneity of the studies involved it was not possible to statistically assess the differences that may exist between the various data sets. As such average survivals were used to facilitate comparison between the various groups.

Results

Literature search

The primary electronic search yielded 983 publications. After removing duplicates 612, the titles were re-assessed, leaving 67 papers. From this, the abstracts were assessed, leaving 29 papers. The full texts for these publications were sourced and following full evaluation a further 17 papers were excluded. Therefore, 12 studies published between 2010 and 2018 were included in this review. The described process can be seen in Figure 1 and the reasons for exclusion in Table 1. The final 12 papers were assessed quantitatively and are listed in Table 2.

Study characteristics

The overall included study characteristics are presented in Table 2. Twelve different studies were included in this systematic review. Of these, two were randomised controlled studies, five were prospective and five were retrospective. Implant survival was described in all studies and failure recorded at the point an implant was lost or removed from the patients' oral cavity. Follow-up periods ranged from 12 months to 12 years, with study sizes ranging from 25 to 462 implants. Overall, 620 patients had 1353 implants placed across the 12 included studies. All studies were completed in Universities or specialist clinics. Average residual bone height across the studies was found to be 4.68 mm.

Full intervention characteristics are presented in Table 3. All sinuses were accessed through a lateral window. In four studies, the bone window was removed and then replaced at the end of the procedure. Five studies reported the use of a xenogeneic collagen membrane and two report the use of either the bone window or a xenogeneic collagen membrane. One study utilised a bovine cortical plate and for one study the window was left uncovered. All implants for all studies were placed simultaneously with graft placement. One study used autogenous bone as the grafting material. Four studies used deproteinised bovine bone mineral (DBBM). Five studies utilised blood only. A single two leg study used blood alone for one group of volunteers and DBBM for the other study leg. One study used an allograft. Pre-operative antibiotics were solely utilised in one study and pre- and post-operative antibiotics were utilised in three studies. Five studies

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Table 1 Table representing studies excluded by full paper review and reasoning

Author (year)	Title	Exclusion reasoning
Bortoluzzi *et al*. (2014)	Comparative study of immediately inserted dental implants in sinus lift: 24 months of follow-up	<10 patients
Cricchio *et al*. (2013)	Immediate loading of implants placed simultaneously with sinus membrane elevation in the posterior atrophic maxilla: a two-year follow-up study on 10 patients	<10 patients
Falah and Sohn (2016)	Graftless sinus augmentation with simultaneous implant placement: clinical results and biological perspectives	<12-month follow-up
Kim *et al*. (2014)	Resorption of bone graft after maxillary sinus grafting and simultaneous implant placement	>6 mm residual bone height
Maddalone *et al*. (2018)	Long-term stability of autologous bone graft of intraoral origin after lateral sinus floor elevation with simultaneous implant placement	>6 mm residual bone height
Mazor *et al*.[12]	Sinus floor augmentation with simultaneous implant placement using Choukroun's platelet-rich fibrin as the sole grafting material: a radiologic and histologic study at 6 months	<12-month follow-up
Nedir *et al*. (2015)	Short implants placed with or without grafting in atrophic sinuses: the 3-year results of a prospective randomized controlled study	Inappropriate surgical approach
Peleg *et al*. (2000)	Augmentation grafting of the maxillary sinus and simultaneous implant placement in patients with 3–5 mm of residual alveolar bone height	Inappropriate implant surface
Peleg *et al*. (2006)	Predictability of simultaneous Implant placement in the severely atrophic maxilla: a 9-year longitudinal experience study of 2132 implants placed into 731 human sinus grafts	Inappropriate implant surface
Piattelli *et al*. (2010)	Simultaneous sinus membrane elevation and dental implant placement without bone graft: a 6-month follow-up study	<12-month follow-up
Rajkumar *et al*. (2013)	Implant placement in the atrophic posterior maxilla with sinus elevation without bone grafting: a 2-year prospective study	No implant survival data
Rammelsberg *et al*. (2011)	Prognosis of implants placed in combination with simultaneous bone augmentation	Multiple grafting techniques used
Silvestre *et al*. (2013)	Simultaneous sinus augmentation with implant placement: histomorphometric comparison of two different grafting materials. a multicenter double-blind prospective randomized controlled clinical trial	<12-month follow-up
Tajima *et al*. (2013)	Evaluation of sinus floor augmentation with simultaneous implant placement using platelet-rich fibrin as sole grafting material	<10 patients
Verdugo *et al*. (2017)	Long-term stable vertical bone regeneration after sinus floor elevation and simultaneous implant placement with and without grafting	Inappropriate surgical approach
Yin *et al*. (2016)	Analysis of bone height changes after maxillary sinus augmentation with simultaneous and delayed placement of dental implants: a clinical and radiographic study	>6 mm residual bone height
Zhu *et al*. (2017)	Modified maxillary sinus floor elevation via a mini-lateral window with simultaneous placement of dental implants: a clinical and radiographical study	<12-month follow-up

reported the use of post-operative antibiotics only while three did not report on the use of antibiotics. All implants used in all studies had microroughened surfaces: six used tapered implants only, three used parallel sided implants only and three used a combination of both parallel and tapered designs. Nine studies reported using bone level implants, three used tissue level implants and one a combination of both. The most common complication was perforation of the Schneiderian membrane, reported adequately in four studies. All studies reported on implant survival with these data reported in Table 4.

Assessment of risk of bias and quality

Risk of bias was assessed for all included studies according to the categories included in Table 5. Risk of bias was determined as low, high or unclear in line with the Cochrane Risk of Bias In Non-randomized Studies of Interventions tool, to assess the likely bias associated with an intervention in non-randomised studies[24]. Where more than one category was noted as being at an unclear risk of bias the overall rating of the study was noted as high risk due to multiple shortcomings. Five of the 12 studies were identified as being at high risk of bias.

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Table 2 Table demonstrating study characteristics

Authors	Title	Study design	Setting	Follow-up period (years)	Mean follow-up (years)	Number of patients	Radiographs standardised	Average residual bone height	Industry support	Primary outcomes
Bassi *et al*.[13]	Maxillarysinus lift without grafting, and simultaneous implant placement: a prospective clinical study with a 51-month follow-up	PSA	University	4.25	4.08	17	Yes	5.94	No	Implant survival
Bechara *et al*.[3]	Short (6-mm) dental implants versus sinus floor elevation and placement of longer (≥10-mm) dental implants: a randomized controlled trial with a 3-year follow-up	RCT	University	3	2.87	20	Yes	4.67	No	Implant survival
Cara-Fuentes *et al*.[14]	Long-term outcome of dental implants after maxillary augmentation with and without bone grafting	RC	Private Practice	6	2.26	25	Yes	4.90	No	Implant survival
Cara-Fuentes *et al*.[14]	Simultaneous sinus lift and implant installation: prospective study of consecutive two hundred seventeen sinus lift and four hundred sixty-two implants	RC	Private Practice	6	2.82	26	Yes	5.45	No	Implant survival
Cha *et al*.[15]	Sinus bone formation and implant survival after sinus membrane elevation and implant placement: a 1- to 6-year follow-up study	PSA	University	2	1.98	161	Yes	4.11	No	Implant survival
Cricchio *et al*.[16]	1-stage versus 2-stage lateral sinus lift procedures: 1-year post-loading results of a multicentre randomised controlled trial	PSA	University and Private Practice	3	2.97	84	Yes	5.70	No	Implant survival
Felice *et al*.[17]	Maxillary sinus floor augmentation and simultaneous implant placement using locally harvested autogenous bone chips and bone debris: a prospective clinical study	RCT	University	1	0.97	30	Yes	3.00	No	Implant survival
Johansson *et al*.[18]	A 5-year follow-up of 80 implants in 44 patients placed immediately after the lateral trap-door window procedure to accomplish maxillary sinus elevation without bone grafting	PCC	University	5	2.48	61	Yes	5.49	No	Implant survival
Lin *et al*.[19]	Simultaneous and delayed direct sinus lift versus conventional implants: Retrospective study with 5-years minimum follow-up	PSA	University	5	5	44	Yes	5.06	Grants of unknown origin	Implant survival

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Table 2 (*Continued*)

Authors	Title	Study design	Setting	Follow-up period (years)	Mean follow-up (years)	Number of patients	Radiographs standardised	Average residual bone height	Industry support	Primary outcomes
Romero-Millan *et al.*[20]	Follow-up of the sinus membrane elevation technique for maxillary sinus implants without the use of graft material	RC	University	12	6.82	62	Yes	4.40	No	Implant survival
Riben and Thor[21]	Comparative evaluation of simultaneous maxillary sinus floor elevation and implant placement with residual bone heights greater or less than 5 mm	RCS	University	1	0.95	36	Yes	4.89	No	Implant survival
Soydan *et al.*[22]	Implant survival following sinus membrane elevation without grafting and immediate implant installation with a one-stage technique: an up-to-40-month evaluation	RC	University	1	1	35	Yes	3.93	No	Implant survival
Stefanski *et al.*[23]		RCS	University	1.75	1.75	19	Yes	5.25	No	Implant survival

NA, not assessed; PCC, prospective case control; PIMBL, peri-implant marginal bone loss; PSA, prospective single arm cohort study; RC, retrospective cohort; RCS, retrospective case series; RCT, randomised controlled trial.

Data synthesis and analysis

The 12 studies yielded data on 1353 implants with a mean follow-up period of 2.71 years. Over this period 27 implants failed. Analysis revealed that 22 of these implants failed at or before uncovering (1.62%) with a further four lost after 1 year of loading (0.30% of remaining implants) and one further implant lost after 2 years of function (0.01% of implants). Beyond this point no implants were reported as failed in any study. Overall 2.04% of all implants failed. The longest follow-up was 12 years and the shortest 12 months. The longest mean follow-up time was 6.82 years.

Comparison was made between implants placed into sinuses with and without grafting material. There were six studies for comparison using graft material and five using blood only, with one study having two arms, one which fitted into each group.

For the group using blood in the sinus, analysis found that that 15 of these implants failed at or before uncovering (1.47%) with a further two lost after 1 year of loading (0.45% of remaining implants). No further implants were lost beyond this point. Overall 1.89% of total implants in this group failed.

For the group using grafting materials analysis found that that 7 of these implants failed at or before uncovering (1.77%) with a further two lost after 1 year of loading (0.24% of remaining implants) and one further implant lost after 2 years of function (0.15% of remaining implants). No further implants were lost beyond this point. Overall 2.13% of total implants in this group failed.

Discussion

The rationale behind the undertaking of any sort of sinus floor elevation is that the residual bone height is deemed inadequate to provide stability for the long-term success of a dental implant supporting a functional prosthesis. The currently well-established two-stage sinus floor elevation technique has been heavily studied with long-term outcome results readily available. When these techniques are completed with the considered gold standard techniques, success can be expected to exceed 96.3%[4].

This technique has evolved to allow the placement of dental implants simultaneously with grafting from a lateral approach, a method that has developed in response to newer implants that can achieve primary stability in reduced residual bone height[25] and patient demand for treatment with fewer surgical interventions and less treatment time. Within this

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Table 3 Table demonstrating study interventions

Authors	Pre-op Abs?	Post-op Abs	No Abs	No mention of Abs	Graft material	Barrier over window	Membrane tears %	Total sinuses augmented	Number of implants	Implant surface	Implant shape	BL or TL
Bassi *et al.*[13]	NR	NR	NR	Yes	Blood	Yes	n/a	20	25	MR	T	BL
Bechara *et al.*[3]	Yes	Yes	No	No	DBBM	Yes	n/a	NR	45	MR	T	BL
Cara-Fuentes *et al.*[14]	NR	NR	NR	Yes	DBBM	Yes	n/a	28	38	MR	T+P	BL
Cara-Fuentes *et al.*[14]	NR	NR	NR	Yes	Blood	Yes	n/a	29	38	MR	T	BL
Cha *et al.*[15]	NR	Yes	No	No	DBBM	Yes	16.12	218	462	MR	T	BL
Cricchio *et al.*[16]	NR	Yes	No	No	Blood	Yes	n/a	96	239	MR	T	BL
Felice *et al.*[17]	Yes	Yes	No	No	DBBM	Yes	n/a	NR	65	MR	T	BL
Johansson *et al.*[18]	No	Yes	No	No	Autogenous intra-oral	Yes	n/a	NR	82	MR	P	TL
Lin *et al.*[19]	Yes	NR	No	No	Blood	No	n/a	NR	80	MR	T+P	TL+BL
Romero-Millan *et al.*[20]	NR	Yes	No	No	BTP	Yes	n/a	75	113	MR	T	BL
Riben and Thor[21]	Yes	Yes	No	No	Blood	Yes	37.7	53	87	MR	T+P	BL
Soydan *et al.*[22]	NR	NR	NR	Yes	DBBM	Yes	2.38	42	51	MR	P	TL
Stefanski *et al.*[23]	NR	Yes	No	No	Blood	Yes	27.27	22	28	MR	P	TL

NR, not recorded; MR, microroughened; T, tapered; P, parallel; DBBP, deproteinised bovine bone mineral; BTP, beta tricalcium phosphate; BL, bone level; TL, tissue level.

technique the purpose of the grafting material has been entirely to form a scaffold from which a stabilised coagulum can differentiate into new native bone.

The need for this scaffold has been challenged by clinicians that have advocated the ability of the simultaneously placed dental implants to act as 'tent poles' for the Schneiderian membrane, creating void into which bone can differentiate from the coagulum[26].

The 12 included studies report on a total of 1353 dental implants with a mean follow-up time of 2.71 years. 1.62% of implants failed at or prior to uncovering, 0.3% were lost within 1 year of loading and 0.01% were lost between 1 and 2 years of loading. Overall 2.04% of implants failed giving a success rate (97.96%) comparable, if not slightly higher than the survival of implants placed via a two-stage approach[4]. This is encouraging as it demonstrates that overall the simultaneous approach to lateral sinus augmentation and implant placement is predictable. When comparison is made between the groups using graft material and blood alone, the blood group demonstrate marginally higher overall survival rate of 98.11% versus 97.87%.

Comparison of studies is often challenging due to heterogeneity. To gain a more homogenous sample, specific search criteria were applied. Due the heterogeneity in study design it has not been possible to statistically assess the results for any difference of significance. Nonetheless, it can at least be stated that the two different techniques have comparable success rates which lends itself well to the newer 'blood only' graft technique. This is unsurprising as the role of the biomaterial is solely to provide a scaffold, and it is known that if the space can be preserved the coagulum can differentiate into bone[26–29].

The only paper to directly compare the two different interventions as separate arms on a study found a higher success for blood when compared to graft, although it should be noted that this study[14] had a small sample size, poor follow-up and was deemed at high risk of bias. The results should therefore be interpreted with caution.

The most commonly reported complication of the procedure was perforation of the sinus membrane which was reported in four studies with a frequency of 20.89%. This is in line with the literature (19.5%)[4], was not noted to impact the success of the implants placed, and none of the procedures were abandoned as the result of perforation. These data are in keeping with the existing modern literature which suggests that the creation of a perforation does not increase the failure rate of laterally

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Table 4 Table demonstrating implant survival times

Authors	Implants failed at indicated time point post loading (total implants remaining in study at this point)														Total number of failed implants
	0 months	6 months	12 months	18 months	21 months	2 years	3 years	4 years	4.25 years	5 years	6 years	7 years	8 years	9 years	10 years	12 years	
Bassi *et al.*[13]	1 (25)								0 (24)								1
Bechara *et al.*[3]	2 (45)		0 (43)				0 (43)										2
Cara-Fuentes *et al.*[14]	0 (38)		0 (26)			0 (16)	0 (16)	0 (15)		0 (7)	0 (6)						0
Cara-Fuentes *et al.*[14]	0 (38)		0 (37)			0 (30)	0 (17)	0 (11)		0 (6)	0 (6)						0
Cha *et al.*[15]	4 (462)					1 (458)											5
Cricchio *et al.*[16]	2 (239)	0 (237)	1 (237)	0 (236)		0 (236)	0 (236)										3
Felice *et al.*[17]	2 (65)		0 (63)														2
Johansson *et al.*[18]	1 (82)		0 (81)			0 (58)	0 (34)	0 (20)		0 (10)							1
Lin *et al.*[19]	0 (80)		0 (80)	0 (80)		0 (80)	0 (80)	0 (80)	0 (80)	0 (80)							0
Romero-Millan *et al.*[20]	6 (113)		0 (107)							0 (107)	0 (67)	0 (62)	0 (53)	0 (29)	0 (21)	0 (2)	6
Riben and Thor[21]	4 (87)		1 (83)														5
Soydan *et al.*[22]	0 (51)		2 (51)														2
Stefanski *et al.*[23]	0 (28)				0 (28)												0

approached sinus lifts[4], which has superseded the previous consensus that membrane perforation did detrimentally affect the success of the augmentation procedure[30]. The fact that perforation does not seem to affect the success of these grafts is interesting as this theoretically provides a route through which they may be contaminated by bacteria present in 62.3% of maxillary sinuses[31]. The perforations were addressed by a variety of techniques including an increase in the extent of membrane elevation, the use of a resorbable membrane or suturing.

A further factor demonstrated to influence graft survival is the placement of a covering material over the sinus window, whether bone or a membrane, as the absence of any method of window closure has been associated with a 4.04% increase in annual implant failure rate, resulting in a 3-year implant survival rate of 88.6%[4]. Pjetursson *et al.*[4] considered that the increased failure rate is likely associated with the increased possibility of graft contamination, either bacterially or from ingress of soft tissue. Interestingly, for the one included study where no window covering was placed[19], none of the implants failed. This is a robust result as the entire sample was followed up for the duration of the 5-year study.

Due to a paucity of evidence (only two RCTs meeting the inclusion criteria), prospective and retrospective cohort, prospective single arm uncontrolled cohort study and case series meeting all inclusion criteria were included for evaluation. Differentiating between a case series and a single arm uncontrolled cohort study is challenging but it has been suggested that a single arm cohort study can be identified if it has a protocol prior to data collection, inclusion and exclusion criteria and a standardised follow-up procedure including reporting of loss to follow-up[32]. Prospective studies are widely considered to offer a higher level of evidence than retrospective studies, which may be subject to greater bias. The results from the two groups were compared and the retrospective studies were found to have lower survival, suggesting that biases had not influenced the strength of the assessed interventions.

A limitation of this study is the relatively short follow-up period available. This is of importance because in all included studies, of the total 27 implants that failed, 22 of these failures occurred prior to loading, four between 6 and 12 months in function and one between 12 and 24 months in function. This indicates that of the reduced number of implants returning at different intervals of the studies still ongoing at 4 years, none of the remaining 257 implants were noted as having failed, nor

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Table 5 Table summarising the risk of bias in the included studies

	Confounding bias	Selection bias	Classification bias	Deviations from intended interventions bias	Missing data bias	Outcome bias	Reporting bias	Overall assessment
Bassi *et al*.[13]	Low	Low	Unclear	Low	Low	Low	Low	Unclear
Bechara *et al*.[3]	Low	Low	Low	Low	Low	Low	Low	Low
Cara-Fuentes *et al*.[14]	Low	Low	Low	Unclear	High	Low	Low	High
Cha *et al*.[15]	Low	Low	Unclear	Low	Low	Low	Low	Unclear
Cricchio *et al*.[16]	Low	Low	Low	Low	Low	Low	Low	Low
Felice *et al*.[17]	Low	Low	Low	High	Low	Low	Low	High
Johansson *et al*.[18]	Low	Low	Unclear	Low	High	Low	Low	High
Lin *et al*.[19]	Low	Low	Low	Unclear	Low	Low	Low	Unclear
Romero-Millan *et al*.[20]	Low	Low	Low	Low	Low	Low	Low	Low
Riben and Thor[21]	Low	Unclear	Unclear	Unclear	Low	Low	Low	High
Soydan *et al*.[22]	Low	Low	Low	Low	Low	Low	Low	Low
Stefanski *et al*.[23]	Low	Unclear	Unclear	Low	Low	Low	Low	High

The colour shades represent relative risk of bias with red being high and green being low. Orange represents an unclear risk of bias.

any of 210 reviewed after 5 years or the 21 remaining under observation after 10 years. This highlights that failure is very heavily weighted towards the very early stages of this treatment and therefore if the implants survive for 12 months the augmentation procedure can likely be considered a 'success'. Furthermore, from this point implants that fail may be assessed in accordance with all other methods of failure that afflict all types of dental implant placed into pristine sites.

This is particularly important as a large criticism frequently levelled at xenografts is that bone does not form in the grafted areas, whereas autogenous bone alone will differentiate from a blood clot. One further consideration is that all studies were completed in university and specialist practice settings, so the results may not be entirely transferable to a general practice environment with perhaps less experienced surgeons[33].

The different implant designs did not seem to have any impact on the survival of the implants placed, whether they be tapered or parallel sided, even though it has been noted that tapered implants more readily achieve high primary stability values than parallel sided implants. This may be because only rough-surface implants were included in the inclusion criteria as this has previously been determined as having a positive effect on the survival of dental implants when compared to machined surfaced, particularly in sinus graft procedures[4].

One limitation of previous studies is that they have allowed the inclusion of implants placed into residual bone heights of 6 mm and greater. With the most recent research indicating that implants that would previously have been thought of as 'too short' (i.e. 6 mm) proving highly successful[34] it is important that all papers not reporting residual bone height or reporting a mean residual bone height ≥6 mm have all been excluded as the implants would likely be successful irrespective of the success of any grafting procedures.

From all studies undertaken it can be noted that three implants failed prior even to uncovering as a result of infection[3,15]. These infections were all grouped in patients who underwent grafting. Although the sample is too small to assess statistically it may be speculated that there is an increased risk of infection as more biomaterials are included in the treatment. This presents a problem avoided as, with the exception of the dental implants themselves, no foreign materials are introduced. While considering the risk of infection it is important to note that nine of the studies considered explicitly utilised an antibiotic regime, and for the remaining three no mention was made of antibiotics, so it is unclear if they were used or not. This is relevant as it has been demonstrated that when antibiotics are utilised there is a significantly reduced risk of early failure. The number needed to treat to prevent one failure is 25 with preoperative dose of 2-3 g amoxicillin[35].

Although economic data have not been utilised for this study it is recognised that biomaterials are expensive and that the avoidance of using biomaterials may reduce the overhead of a procedure, which may reduce the overall financial burden of treatment. One area of interest is the use of fractionated blood products to encourage healing. Although not specifically excluded by this search the few available

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papers were excluded by other criteria such as inadequate follow-up time[12]. However, the research that is available at this point is yielding promising results and is an area that is likely to develop further over the coming years. This is particularly interesting as one of the greatest limitations of the graftless approach has been noted as the containment of the blood clot within the sinus, with authors advocating opening the lateral window of the sinus some 5 mm above the floor of the sinus with a view to creating a three-walled containment unit for the blood[25]. The downside of this is that the technique is clinically much more challenging and likely to lead to intraoperative complications such as Schneiderian membrane perforation due to the more challenging angulation required from the membrane elevation instruments. This can be negated to an extend because autologous blood factors may be presented as a stabilised form of clot with structure that can be physically inserted and hold its own form. This allows for a more conventional lower approach to the creation of the lateral window.

Due to the limited literature surrounding this topic it is challenging to compare these findings, particularly as all studies of reasonable quality were included in this review. Although there are few studies for comparison, this relatively new technique appears to have scope to improve the future care of patients.

Strengths and limitations of this systematic review

Observation of the principals outlined in the Cochrane Handbook of Systematic Reviews allowed the formulation of a well-defined search strategy and subsequent literature search to identify the studies relevant to the research question. This forms one of the first reviews to compare these two treatment modalities with a reasonable follow-up period.

Although the follow-up period in this study is greater than previous studies it is important to recognise that not a single included study thoroughly described the process by which the patients were followed up. Furthermore, no studies advised whether or not they had maintained all patients throughout[19] or whether any were lost at variable intervals[18]. This is troubling as it indicates a lack of clear planning and execution which may compromise the validity of conclusions drawn from this study and further reinforces the necessity for more robust future studies.

A limitation of this review is that it a single author (PJK) completed the data search and assessments of bias. English published literature alone was considered, with the absence of both non-English language and unpublished data from the grey literature leading to publication bias. Although there are increased numbers of papers published around this area the strength of the evidence is still relatively weak due to the lack of higher-powered study designs. However, the available studies used comparable study designs and relatively standardised surgical techniques should allow effective comparison and analysis.

Recommendations for future research

The limitations of this study are acknowledged, as is the lack of well-designed prospective randomised controlled trials on these treatments. Therefore, future efforts should be directed at increasing the quality of research over longer periods of time around this.

Conclusion

This review of implant data studies confirms that placing dental implants into maxillary sinuses with a graftless approach yields comparable implant survival to those cases that are grafted. This suggests that there is scope to simplify treatment protocols, decrease the risk of infection while maintaining treatment success and increase patient acceptance of sinus lift procedures.

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Competing Interests

The authors declare that there was no conflict of interest during this study.

Ethical approval

This was not required for this study as human subjects were not involved.

Patient consent

This was not required as human subjects were not involved.

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