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Maxillary Sinus Lift: An evidence based review

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Abstract

Sinus lift techniques were introduced to enable implant placement and prosthetic reconstruction of posterior maxilla with insufficient alveolar bone. Diminished bone height in the posterior maxilla can be modified by grafting the sinus which creates adequate bone for implant placement making the procedure advantageous for posterior maxillary edentulism even in atrophic cases. There are various procedures to reconstruct the posterior maxilla. The technique for sinus elevation includes crestal osteotome technique and the lateral window technique. It

also increases the quality of bone, increases primary implant stability and decreases implant failure. Sinus lifting enables implant placement with improved esthetics and optimal function. In this article, based on the evidence of case reports, prospective/retrospective studies, RCTs, systematic reviews and meta analyses, we had discussed about the sinus lift techniques and modifications, graft materials used to augment sinus and complications of sinus lift in detail and also reviewed the current literature.

Keywords: maxillary sinus, dental implant, crestal approach, lateral window technique, perforation, bone graft

Introduction

Maxillary sinus is a pyramidal shaped air cavity located in the maxilla. The sinus opens through the ostium into the middle meatus and is lined by schneiderian membrane which is adherent to the underlying bone ^[1]. It is the largest paranasal sinus containing 12-15 ml of air ^[2]. The walls and the membrane of the sinus are supplied by posterior superior alveolar artery, inferior orbital artery, greater palatine and sphenopalatine artery, the branches of maxillary artery ^[3]. The floor of the sinus extends from the premolar or canine region anteriorly to the tuberosity posteriorly with the lowest extension near the first molar area ^[4]. Inside the sinus, it may be divided into multiple compartments by bony septa called Underwoods septa⁵ which is present in 16-58% ^[6,7] of cases.

Pneumatization is a physiologic process that occurring in sinuses during the growth period leading to increase in volume. Pneumatization of sinus ends at 20 years of age and reaches 5mm inferior to the nasal floor ^[8-10]. Maxillary sinus pneumatization resumes in adults after posterior tooth extraction. This pneumatization occurring after tooth extraction is a type of disuse atrophy and reduced bone height due to pneumatization is caused by increase in positive intra antral pressure⁶ and increased osteoclastic activity of the periosteum of the schneiderian membrane ^[7].

The vertical bone loss occurring after extraction tends to stabilize slowly at a rate of 0.1 mm which may vary among individuals. This variation may be attributed to hormonal imbalances, metabolic factors, inflammation, age and gender.⁵ This type of defect can result in improper implant crown ratio by restricting the implant being placed ^[1]. In order to overcome this issue, sinus lift techniques were introduced by Tatum followed by Boyne and James in 1980 enabling implant placement and prosthetic reconstruction. Sinus lift is indicated if there is insufficient residual bone height (less than 10 mm) ^[5], decreased interarch space ^[11], decreased density of bone ^[11], severely atrophic maxilla and no history of sinus pathosis ^[5]. Diminished bone height in the posterior maxilla can be modified by grafting the sinus which creates adequate bone for implant placement making the procedure advantageous for posterior maxillary edentulism even in atrophic cases ^[5]. It also increases the quality of bone, increases primary implant stability and decreases implant failure ^[12].

However it has complications like infraorbital nerve injury, incision line opening, membrane perforation, oroantral fistula, graft loss/failure, implant migration and implant failure ^[5]. A three dimensional radiographic analysis like CBCT is essential for planning the shape and position of antrotomy and for diagnosis and treatment planning of common sinus pathologies like oroantral communication, mucosal thickening, mucous retention cysts and sinus polyps.⁵ The techniques for sinus elevation includes crestal osteotome technique by Summers (1994) and the lateral window technique which are conventional methods followed by the modification of these techniques including piezoelectric, ultrasound, balloon elevation, DASK technique and CAD/CAM approach. In this article, based on the evidence of case reports, prospective/retrospective studies, RCTs, systematic reviews and meta analysis, we shall review the best evidence of sinus lift based on the techniques, graft materials and complications.

Compilation of case reports, prospective/retrospective studies, RCTS and systematic reviews & meta analyses

Table 1

Systematic Reviews And Meta Analysis								
S no	Author	Year	Objective of the review	Total articles selected	Articles that met the inclusion criteria	Follow up of all articles	Type of implant (placement/ brand/ size)	Conclusion
1	Tan WC <i>et al.</i> ^[13]	2008	To assess the implant survival rates placed using transalveolar sinus lift technique	849	19	3.1 years	ITI, Osseotite, Astra Tech, Dentsply etc	The survival rate of implants for 3 years using transalveolar technique was 92.8% which decreases with decreasing alveolar bone height.
2	Pjetursson <i>et al.</i> ^[14]	2008	To assess the implant survival rates placed using lateral window sinus lift technique	839	48	3 years	ITI, Branemark, Astra Tech etc	The survival rate of implants for 3 years using lateral window technique was 90.1% with a failure rate of 16.6% (subject based) and 3.5% (implant based) .
3	D. Rickert <i>et a</i> ^[115]	2012	To assess the implant survival rate and bone fraction after sinus lifting and to evaluate if the bone fraction is affected by the grafting materials or growth factors	1124	12	6 to 20.2 months	NR	For a healing period of atleast 5 months, bone substitutes like Bio-Oss, Bioactive glass or cotiocancellous pig bone in combination with autograft can be used as an alternative for autogenous bone alone in maxillary sinus lift. Implant survival rate which is a major clinical outcome does not change with grafting materials when a sufficient healing time is provided.
4	Rocio Antonaya Mira <i>et al.</i> ^[16] (Meta analysis)	2012	To compare and evaluate the variations in the sinus lift with osteotomes in terms of increase in height, osseointegration period and implant success	NR	11	6 months to 12 years	Immediate implant placement (ITI, ASTRA)	Following sinus lift with osteotomes, the gain in bone height varied from 2.28 mm and 5.55 mm with the most commonly occurring complications being membrane perforation and BPPV. The average osseointegration period was 4.8 months with a success rate of 94.1% for a follow up period of 1 year.
5	Jessica Cabezas Mojon <i>et al.</i> ^[17] (Meta analysis)	2012	To evaluate the implant survival rate for various graft materials used in sinus augmentation	NR	16	6 months to 12 years	948 Immediate implant placement 2433 Delayed implant placement	The effects of bone substitutes following sinus augmentation are comparable to autologous bone when used alone or in combination with them. Implant survival rate is higher with roughened implants and decreases with simultaneous implant placement following sinus lift.
6	Fabian Duttonhoefer <i>et al.</i> ^[18] (Meta analysis)	2013	To compare and evaluate the influence of treatment modalities, residual bone height, type of graft, type of implant and the use of membranes on implant survival rate following sinus augmentation	1960	106	1 year for most studies except for one study with 11 years follow up	Immediate / Delayed implant placement	No particular treatment modality, graft material and residual bone height influences the success of implants following sinus lift. However, the use of membrane is of major significance for the long term success of implant following augmentation.
7	Mahmoud Al Dajani <i>et al.</i> ^[12]	2014	To describe the recent trends in sinus lift surgery, their surgical advancements, bone grafting and implant survival	8844	37	1 to 3 years	NR	Assessment of pre implant bone quality and quantity is necessary in the posterior maxillary region where a sinus lift is planned when the residual bone is less than 10 mm. Depending upon the quantity of bone

								available, osteotome (more than 5 mm) or lateral window (less than 5 mm) technique is chosen and augmentation should be done with combination of autogenous bone and bone substitutes with maximum care to avoid the membrane perforation.
8	Ginnady Pinchasov <i>et al.</i> ^[19]	2014	To assess the bone formation within the sinus after sinus lift without the use of bone graft materials	2205	19	Atleast one year	Immediate implant placement	Maxillary sinus lifting without the use of graft materials is a reliable technique due to the high potential of maxillary sinus to heal and form new bone.
9	Sara Perez Martinez <i>et al.</i> ^[20] (Meta analysis)	2015	To evaluate the treatment outcome of indirect sinus lift done without the graft materials in terms of bone height gained after implant placement.	289	12	10.43±5.01 years	NR	When the residual bone height is between 5 to 9 mm, indirect sinus lifting without bone graft can be used as a predictable treatment method with an average gain of 3.43±0.09 mm in bone height and survival rate ranging between 93.5% to 100%.
10	Mick P Kelly <i>et al.</i> ^[21] (Meta analysis)	2015	To evaluate the efficacy of recombinant human bone morphogenetic protein - 2 (rh BMP 2) as a graft material for localized ridge augmentation and sinus lift and associated adverse events.	10	6 (ridge augmentation) 4 (sinus lift)	3 to 9 months	NR	Recombinant human bone morphogenetic protein (rh BMP 2) aids in increasing bone height in localized ridge augmentation where as it doesn't produce promising results as compared to sinus augmentation.
11	Guo Hao Lin <i>et al.</i> ^[22] (Meta analysis)	2015	To compare and evaluate the effect of recombinant human bone morphogenetic protein 2(rh BMP 2) on sinus volumetric and histometric changes with conventional non biologic bone graft materials after sinus augmentation.	815	6	3 to 9 months	NR	rhBMP2 produced comparable clinical and histometric results to conventional sinus grafting after healing period of 6 to 9 months. Lesser morbidity and improved patient reported outcomes are seen with rhBMP2 use when compared to autografts.
12	Silva <i>et al.</i> ^[23]	2016	To compare if the sinus lift can be done with or without graft material	1037	16	6 months to 11 years	Nobel biocare, Straumann, MIS implant,Dentsply etc	Sinus lift without graft material is possible and produces similar results as comparable to sinus lifts with grafting and is also cost effective and less time consuming.
13	Rakshith Hedge <i>et al.</i> ^[24]	2016	To evaluate the direct sinus lift technique without the use of graft materials and assess the new bone formation, implant survival rate, implant stability and complications.	1333	18	6 to 64 months	Delayed implant placement (Astra, ITI)	Direct sinus lift without graft materials is a viable treatment option for posterior maxilla with a bone gain of 2.37 to 10 mm and survival rate of 79.9 to 100% as compared to conventional treatment option.
14	Alberto Monje <i>et al.</i> ^[25] (Meta analysis)	2016	To assess the patient related factors that influence the sinus membrane thickness and also to evaluate the association between the membrane thickness and perforation.	576	19	NR	NR	Factors such as periodontitis and smoking may influence the sinus membrane thickness but the data from the meta analysis is inconclusive to find the association between membrane thickness and membrane damage.
15	Francisco Correia <i>et al.</i> ^[26]	2017	To assess the use of regenerative medicine in sinus lift procedures in terms of bone gain and implant	430	18	4 to 78 months	14 studies- Delayed implant placement 4 studies- immediate	The use of regenerative techniques in sinus lift aids in vital bone formation with residual grafts.

			osseointegration.				implant placement	
16	V. Moraschini <i>et al.</i> [27] (Meta analysis)	2017	To evaluate the efficacy of sinus lift with immediate implant placement without the use of graft materials.	730	18	39.4 months	Immediate implant placement (Straumann, Astra Tech, Osseo speed, Nobel biocare, Neoss)	Maxillary sinus lifting with immediate implant placement without the use of graft materials results in average gain of 4.7 mm in bone height with a high success and survival rate of 97%.
17	Ronaldo Silva Cruz <i>et al.</i> [28] (Meta analysis)	2018	To compare short versus long implants for sinus augmentation in terms of survival rates, marginal bone loss, biologic and prosthetic complications	26	11	9 to 36 months	Zimmer Biomet, Straumann, Dentsply Implants, MegaGen and Southern Implants	Lesser biologic complications with comparable survival rates and marginal bone loss makes short implants as an effective alternative to sinus augmentation with long implants, except for the increased risk of prosthesis associated mechanical failures in short implants.
18	Marcelo Parra <i>et al.</i> [29]	2018	To estimate the survival rates of implants placed in the maxillary posteriors after a graftless sinus lift using a lateral window technique and to identify the influencing factors.	232	11	12 to 72 months	Immediate implants	Graftless maxillary sinus lift using lateral window technique shows high implant survival rate with new bone formation, however the exact indication of this technique is yet to be discovered.
19	Javier Romero M <i>et al.</i> [30]	2018	To compare and evaluate the conventional implant placement and implant placed after open sinus lifting for implant survival, marginal bone loss, Periimplant clinical parameters and complications.	90	23	6 to 120 months	(Nobel, Astra, ITI and Branemark)	Implants placed conventionally in native bone is comparable to implants placed after sinus augmentation in terms of survival rate, marginal bone loss and other clinical parameters except for increased complications associated with sinus lifting.
20	Mingdong Yan <i>et al.</i> [31]	2018	To evaluate the clinical outcomes after transalveolar sinus lift without the use of graft materials in atrophic maxilla.	2601	18	4 to 120 months	6 to 13 mm in length	The implant survival rate was 98% in the graftless technique with not much significant difference from the grafted sinuses making the transalveolar graftless sinus lift, a predictable method of treatment.
21	Mokchech <i>et al.</i> [32]	2018	To compare short implants and standard implant placement along with sinus lift in terms of clinical outcomes, morbidity and patient satisfaction.	480	18	4 to 47 months	Immediate implant placement except 3 studies (MegaGen Implants)	Short implants are reliable alternative to standard implants with sinus lift due to fewer complications, comparable survival rates and favorable patient reported outcomes.
22	Huda Moutez Asmael <i>et al.</i> [33]	2018	To compare and evaluate the antral membrane balloon elevation technique with transalveolar technique in terms of bone gain, success rate, survival rate and complications.	5395	10	6 to 23 months	10 to 17.1 mm in length and 3.75 to 6.5 mm in diameter (immediate implant placement)	Minimally invasive antral membrane balloon elevation technique has the ability to produce ≥ 10 mm of bone gain comparable to lateral window and transalveolar technique in a minimally invasive manner.
23	E.A. Al Moraissi <i>et al.</i> [34] (Meta analysis)	2018	To compare and evaluate if membrane perforation increases the risk of implant failure following sinus lift and to assess the implant loss in perforated and non perforated sinuses.	480	58	6 months to 8 years	NR	The risk of implant failure increases with sinus membrane perforation with statistically significant difference between perforated and non perforated sinus in the failure rate.

24	Gian Maria Ragucci <i>et al.</i> [35]	2019	To assess and evaluate the implants intruding into the sinus cavity in terms of survival rate and complications.	3551	8	52.7 months	NR	Implants intruding into the maxillary sinus without sinus augmentation have a high survival rate of 95.6% irrespective of the level of implant penetration (less than/ greater than 4 mm). The common complications include epistaxis and accumulation of debris on the implant surface leading to sinusitis with no significant difference in complication rate.
25	T.C. Nino Sandoval <i>et al.</i> [36]	2019	To evaluate the efficacy of stem cells in bone repair following maxillary sinus augmentation.	590	10	3 months to 3 years	Straumann implants, Black fix implants etc	Stem cells do not contribute significantly to implant survival rate as well as to efficacy of bone regeneration when used for grafting in sinus lift procedures.
26	Faris Younes <i>et al.</i> [37]	2018	To evaluate the patient reported outcomes after sinus lifting by lateral window technique.	2444	11	Day 1 to 17 years	NR	Pain and edema is the most commonly occurring discomfort following sinus lifting with peak intensity on the day of surgery or on the first post operative day. From this review it was concluded that only moderate discomfort is experienced after sinus lifting.
27	Holmes Ortega- Mejia <i>et al.</i> [38]	2020	To evaluate the effect of platelet concentrate alone and in combination with other graft materials for sinus augmentation in terms of bone formation, bone height and clinical outcomes such as implant survival and stability.	132 (PRF alone) 74 (PRF+ Graft)	11 (PRF alone) 12 (PRF+ Graft)	6 months to 6 years (PRF alone) 1 week to 2 years (PRF+ Graft)	Immediate implant placement (PRF alone) Delayed implant placement (PRF+ Graft)	There are no strong evidences to confirm the beneficial effects of sole use of platelet concentrates in sinus augmentation however evidences suggesting their favorable outcomes regarding implant survival, bone height and bone gain are present. Similarly, combined use of PRF with other graft materials does not have additional effects but they improve wound healing and bone formation.
28	V. Apparaju <i>et al.</i> [39]	2020	To compare and evaluate Balloon assisted maxillary sinus floor augmentation with crestal and lateral window approaches in terms of complications and bone gain after long term follow up.	73	8	6 months to 2 years	Immediate implant placement (except 2 studies due to unavailability of bone)	Balloon assisted maxillary sinus floor augmentation causes lesser membrane perforation and other complications with a higher bone gain.
29	Yushen meng <i>et al.</i> [40]	2020	To evaluate the efficacy of autologous platelet concentrate (APC) combined with bone grafting for sinus augmentation.	300	11	4 to 24 months	NR	The use of PRP/ PRF in sinus augmentation had no additional effects when combined with osteoconductive materials in terms of new bone formation and implant stability. But it is also advantageous as it aids in reduction of healing time, post operative symptoms and time for graft maturation allowing for early implant placement.
30	Narora Lozano Carrascal <i>et al.</i> [41] (Meta analysis)	2020	To compare and evaluate the short implants (<8 mm) and long implants (>8 mm) placed after sinus augmentation in terms of survival rate, marginal bone loss and complications.	482	8	1 to 3 years	Immediate implant placement [10 to 15 mm in length(long implants) and 4 to 6 mm (short implants)]	Short implants can be successfully used as an alternative for sinus augmentation with long implant placement with no statistically significant differences between them in terms of complications and survival rate. However, marginal bone loss is higher in long implant group with sinus augmentation.

Table 2

Randomized Controlled Trials										
S no	Author	Year	Age of the patients	Technique used	Type of implant (placement/ brand/ size)	Type of graft	Follow up	Radiographic technique	Complications	Conclusion
1	Bettega <i>et al.</i> [42]	2009	Above 18 years	Lateral window technique	Delayed implant placement (6 months after grafting)	Iliac crest graft + APC on one side Monobloc corticocancellous graft on the other side	1 year after implant placement	CT	Nil	The use of APC aids in enhancing the bone volume but there is no significant difference in histologic / mechanical characteristics
2	Felice P <i>et al.</i> [43]	2014	Above 18 years	Lateral window technique	Group A- Immediate implant Group B- Delayed implant after 4 months	Anorganic bovine bone	5 years after loading	CT	Group A- 2 complications a) Intraoperative membrane perforation b) Inability to stabilize an implant Group B- 1 complication a) Graft failure	Both 1 stage and 2 stage sinus lift produced comparable results, but the risk is high for one stage when the residual bone is 1 to 3 mm.
3	Trombelli L <i>et al.</i> [44]	2014	Above 18 years	Transcrestal sinus floor elevation with minimally invasive smart lift technique	Immediate implant placement (Element RC Inicell implant)	Group A – Deproteinized bovine bone mineral Group B – Beta tricalcium phosphate	6 months	CT	Group A – one membrane perforation Group B – 4 membrane perforation + 1 BPPV	Both DBBM and Beta TCP supports sinus lift when done with smart lift technique, however differences in clinical outcomes and post operative morbidity is yet to be found.
4	Felice P <i>et al.</i> [45]	2015	Above 18 years	Group A- Crestal technique Group b- short implants	Immediate implant Group A- 10 mm or longer (cosci advanced sinus kit) Group B- 5 or 6 mm long 5(Zimmer Biomet)	Group A- granular anorganic bovine bone substitute Group B- nil	1 year after loading	CBCT	Nil	Both short implant group and crestal sinus lift group produced excellent results with no significant differences for a follow up period of up to 1 year. Hence the selection of technique depends upon the clinician's interest.
5	Daniel S Thoma <i>et al.</i> [46]	2015	20 to 75 years	Group short (GS)- No sinus lifting Group graft (GG)- Lateral window technique	Immediate implant placement GS-Short implants (6*4mm) GG- Long implants (11*4 mm, 13*4 mm and 15*4 mm)	GS- No graft GG- Particulate bovine bone graft	1 year	IOPA + OPG + CT + CBCT	GS- a total of 5 complications including 2 surgical related and 3 abutment related like screw fracture, loosening etc GG- a total of 12 complications including 6 surgically related, 1 buccal fistula near incision line, 1 pronounced hematoma, 1 mobile implant and 3 abutment related like loosening.	Short implants for single tooth restoration in posterior maxilla are comparable to long implants with sinus augmentation and are considered better than long implants in terms of patient morbidity, treatment time and price.
6	Elbareki <i>et al.</i> [47]	2016	Group A: 33-50 years Group B:	Group A-Balloon technique in crestal approach Group B- Balloon	Immediate implant placement in both the groups	Group A- no grafting Group B- Biphasic calcium phosphate	6 months	CBCT	Nil	Balloon technique for sinus elevation without graft material and immediate implant placement is a reliable procedure with less post operative complications

			32-53 years	technique in crestal approach	Dentium s-clean super line implant with rounded apex (4.4, 5)D/8,10,12 mm L						
7	Gastaldi <i>et al.</i> [48]	2017	Above 18 years	Group A- Crestal technique Group b- short implants	Immediate implant placement Group A- 10 mm or longer (cosci advanced sinus kit) Group B- 5 or 6 mm long (Zimmer Biomet)	Group A- granular anorganic bovine bone substitute Group B- nil	3 years after loading	CBCT	Group A- 2 complications a) Chipping of composite lining of prosthesis b) Loosening of prosthesis Group B- one complication a) Peri implant mucositis	Both short implant group and crestal sinus lift group produced excellent results with no significant differences for a follow up period of up to 3 years. Hence the selection of technique depends upon the clinician's interest. However the efficacy between the techniques is inconclusive.	
8	Veronika Pohl <i>et al.</i> [49]	2017	20 to 75 years	Group short (GS)- No sinus lifting Group graft (GG)- Lateral window technique	Immediate implant placement GS-Short implants (6*4mm) GG- Long implants (11*4 mm, 13*4 mm and 15*4 mm)	GS- No graft GG- Xenograft	3 years	IOPA + OPG + CT + CBCT	GS- 8 abutment screw loosening/ fracture and 2 decementation of crown GG- 2 abutment screw loosening/ fracture and 1 decementation of crown	Short implants for single tooth restoration in posterior maxilla produced comparable results to long implants with sinus augmentation.	
9	Waleed Fouad <i>et al.</i> [50]	2018	21 to 61 years	Lateral window technique	Immediate implant placement	Group A – no graft materials Group B – Deproteinized bovine bone graft	6 months	CT + CBCT	Group A- Membrane perforation	Sinus augmentation with xenograft or without graft material is a reliable technique, however xenograft group produced better results in terms of bone height gain, bone density and implant stability.	
10	Josh Whitt <i>et al.</i> [51]	2020	Atleast 22 years	Lateral window technique (Piezoelectric technique)	Delayed implant placement	Test sinus – Stem cell based allograft (osteocel plus) Control sinus – Cortico cancellous allograft (alloOss)	2 years	CBCT	Nil	Sinus augmentation with stem cell based allograft resulted in higher percentage of vital bone in just 4 months as compared to allograft.	

Table 3

Prospective/Retrospective Studies											
S No.	Author	Year	Age of the patient	Technique	Type of Implant(placement/ brand/ size)	Type of graft	Follow up	Cumulative survival rate/ success rate	Radiograph	Complication	Conclusion
1	Hyun suk cha <i>et al.</i> [52]	2012	NR	Lateral window technique	Immediate implant placement (Implantium/ 10 & 12 mm in length and 3.3, 3.8, 4.3, 4.8 mm in diameter)	Xenograft	57.1±15.6 years	98.91%	IOPA, OPG and CT	35 membrane perforation, 16 implant failure	Sinus lifting with immediate implant placement could be considered for the treatment of atrophic maxilla with minimum residual alveolar bone height (RABH) if primary stability could be achieved with tapered design of

												implants. Smoking is a potential influencing factor on implant failure whereas membrane perforation did not influence the implant success provided it is repaired.
2	D. Spinelli <i>et al.</i> [53]	2015	54.5 years	Transcrestal Guided Sinus Lift (TGSL) technique	Immediate implant placement (10-13* 4 mm/ Nobel Biocare/ Nobel Active)	No grafting	3 years	98.83%	IOPA, OPG, CT and CBCT	1 implant failure		Transcrestal Guided Sinus Lift (TGSL) is a predictable technique for sinus lifting without graft material.
3	Lucian Chirila <i>et al.</i> [54]	2016	45.5±10.1 years	Lateral window technique	Immediate implant placement (MegaGen/ 10 to 13 mm in length and 3.75 to 5.5 mm in diameter)	Xenograft + autologous bone chips/ allograft+ autologous bone chips/ xenograft + allograft or alloplast	2 years	NR	CBCT	5 maxillary sinusitis 1 membrane perforation		Acute sinusitis can occur as a potential complication following sinus lift which if not managed efficiently can lead to pansinusitis, osteomyelitis, and spread of infection to infratemporal space, orbit etc. Hence care must be taken during the procedure not to obliterate the ostium impairing the sinus clearance.
4	Andreas Sakkas <i>et al.</i> [55]	2016	43.1 ±1.55years	Lateral window technique	Delayed implant placement	Autograft (iliac crest/ buccal sinus wall)	1 year	NR	OPG/ CT	11 membrane perforations, 8 wound dehiscence, 3 abscesses and 2 sinusitis		Membrane perforation during sinus lifting does not have a negative impact on bone graft and dental implants.
5	Fulvio Gatti <i>et al.</i> [56]	2018	Above 18 years	Crestal approach with a special drilling system and hydraulic pressure [CAS (Crestal approach sinus) kit]	Immediate implant placement	Anorganic bovine bone/ no grafting if the residual bone is <2 mm	37.3 months	NR	CBCT, IOPA	No complications		CAS (Crestal approach sinus) kit can be considered as a potential treatment option for minimally invasive crestal sinus surgery.
6	J. Lopez Quiles <i>et al.</i> [57]	2018	48.6 years	Crestal approach [MIAMBE (Minimally invasive antral membrane balloon elevation) technique]	Delayed implant placement (11*4 mm, 13*4 mm, 15*4 mm/ Astra Tech/ Osseospeed)	Bio Oss	15 months	94%	OPG, CT	1 membrane perforation and 1 balloon rupture inside sinus		Minimally Invasive Antral Membrane Balloon Elevation (MIAMBE) technique is a reliable option for sinus lifting since it is simple, safe and minimally invasive.
7	Javier Romero Millan <i>et al.</i> [58]	2018	Control Group- 52.7±12.2 Study Group 1- 54.5±10.6 Study Group 2- 55±9	Control Group- No sinus lifting Study groups 1 & 2- Lateral window technique	Control Group- Conventional implant placement Study Group 1- Immediate implant placement Study Group 2- Delayed implant placement	Beta Tri calcium phosphate	7±1.9 years	Control Group- 89.5% Study Group 1- 44% Study Group 2- 90.1%	IOPA, OPG	NR		Conventional implant placement and sinus lifting with simultaneous and delayed implants produced comparable results in terms of bone loss, success and survival rates except for reduction in graft height in the first 12 months which stabilized around 5 years.

8	Luigi Barbato <i>et al.</i> ^[59]	2018	55.4±8.1 years	Lateral window technique	Delayed implant placement (8-12 mm length/ 3.8-4.8 mm diameter)	Allograft/ Xenograft	6±1.8 years	77%	CBCT/ CT, OPG	12 graft infection, 3 graft failures, 19 implant failures, 4 periimplantitis.	Implant failures in grafted sinuses are significantly associated with the residual bone height and smoking habits of the patient.
9	Ioannis Tilaveridis <i>et al.</i> ^[60]	2018	58 years	Lateral window technique	Immediate implant placement (C Tech/ 13 mm in length and 4.3 or 3.5 mm in diameter)	Mineralized cancellous bone allograft	3 to 8 years	94%	OPG, CBCT	1 membrane perforation, 1 post op infection, 1 premature exposure of healing screw, 1 implant displacement into sinus and 1 implant failure.	Mineralized cancellous human bone allograft can be used a sole material successfully for cases having inadequate residual bone and poor primary stability.
10	Pulkit Khandelwal <i>et al.</i> ^[61]	2020	46.93 years	Lateral window technique (Piezoelectric technique)	Immediate implant placement	Bioactive synthetic calcium phosphor silicate graft	9 months	96.3%	CBCT	1 implant failure	Single stage sinus augmentation is a predictable treatment for patients with deficient residual alveolar height (<5 mm)

Table 4

CASE REPORTS								
S No	Author	Year	Age of the patient	Technique used	Type of implant (placement/ brand/ size)	Type of graft	Radiographic technique used	Conclusion
1	Gray <i>et al.</i> ^[62]	2001	50 years	Lateral window technique	Delayed implant placement	Surgicel (oxidized regenerated cellulose)	MRI	Surgicel can be used as a possible bone graft substitute for sinus lift.
2	Saker <i>et al.</i> ^[63]	2005	41 years	Crestal osteotome technique	Immediate implant placement (4.7 mm D & 13 mm L)	Bio Oss	-	Benign Paroxysmal Positional Vertigo (BPPV) may occur following closed sinus lift which can be managed by medications for motion sickness and Epley maneuver
3	Tobias K Boehm <i>et al.</i> ^[64]	2017	65 years	1) Lateral window technique 2) crestal approach (balloon technique) for right side and lateral window technique for left side which was done palatally, after a year due to incomplete bone formation	Immediate implants a year later	1) 1:1:1 Mixture of cancellous + cortical allograft + bovine xenograft 2) Allograft	CBCT	Incomplete bone formation can be managed by re entry of sinus with with successful implant placement.
4	Karaca <i>et al.</i> ^[65]	2018	45 years	Lateral window technique	Delayed implant placement (5 mm D & 10 mm L)	Autograft (Bone harvested from mandibular tori)	OPG	Mandibular tori is a reliable site for bone graft harvesting with good bone fill and lesser complications than other sites for harvesting autografts.

5	Yitaf Manor <i>et al.</i> ^[66]	2018	35 years	Crestal approach	Immediate implant placement	-	CT and MRI	Maxillary sinusitis following sinus lift should be treated immediately since it can cause life threatening condition like brain abscess .
6	Cristian Adrian Ratiu <i>et al.</i> ^[67]	2018	54 years	Lateral window approach (ultrasound)	Delayed implant placement	Autograft (cortical spongy mixture) + inorganic bovine bone + PRGF	CBCT	Sinus grafting with PRGF and fibrin membrane alone can induce bone formation favouring dental implant insertion.
7	Saturnino Marco Lupi <i>et al.</i> ^[68]	2018	52 years	Lateral window technique (Piezosurgery)	Delayed implant placement	PLGA + Micrograft	CBCT	Autologous micrografts, with minimum biological sacrifice and adequate regeneration can be used effectively in sinus lift.
8	Mahmoud mudalal <i>et al.</i> ^[69]	2019	40 years	Crestal approach (endoscope)	Immediate Implant placement	PRF	CBCT	PESS is a promising method when the residual bone height less than 4 mm. with minimal invasion, less post operative pain and swelling and enhanced healing by PRF.
9	Raghavendra S Medikeri <i>et al.</i> ^[70]	2019	47 years	Lateral window technique	Delayed implant placement	Beta tricalcium phosphate + PRF	OPG + CBCT	A mucocele on appropriate diagnosis and careful evaluation is not an absolute contraindication for sinus augmentation.
10	Hussein S. Basma <i>et al.</i> ^[71]	2020	58 years	Lateral window technique (Piezoelectric technique)	Delayed implant	Deproteinized bovine bone substitute	CBCT	Elevation of PSA with piezoelectric device along with sinus membrane can minimize the hemorrhagic complications during maxillary sinus lift.

Discussion

Sinus lift is used in the absence of insufficient bone for the rehabilitation of posterior maxilla. The conventional techniques of crestal osteotome and lateral window are predictable with implant survival rate of 95.5% and 90.1% respectively [14, 16]. In spite of high success rates, many other techniques have been suggested in the literature. One such advantageous technique is the Balloon assisted sinus lifting which provides a bone gain of up to 10 mm and can be used even without graft materials with immediate implant placement [33, 47]. Another minimally invasive technique which can be used without graft materials and immediate implant placement is the transcristal guided sinus lift (TGSL) [53].

Pertaining to the timing of implant placement, it was found that immediate placement of implants along with sinus lifting had higher failure rate as compared to delayed placement especially if the residual bone height is 1 to 3 mm [17, 43]. Immediate implant placement in the lateral window technique should be considered only if the primary stability is achieved [52]. It is advised to place implants in the native bone rather than sinus lifting due to higher rate of complications.³⁰ However, from the literature it is evident that implant placement in the native bone and by lateral window sinus augmentation produces comparable results [58]. The use of regenerative materials like mesenchymal stem cells results in higher percentage of vital bone within 4 months [51]. Other materials like rhBMP 2 resulted in improved patient reported outcomes [22]. The use of platelet concentrates for sinus grafting does not have any additional effects on bone gain and implant survival [38]. It was found that implant survival rate was not affected by the type of graft material rather than the healing time provided irrespective of the graft material used [15]. Sinus lifting without graft materials also produced clinical outcomes similar to the use of graft materials with bone gain of 4.7 mm and survival rate of 97% [23, 27].

As stated earlier, sinus lifting produces a higher rate of complications. Pain and edema were the most common.³⁷ Potential complications occurring during the procedure include membrane perforation and BPPV. Thicker sinus membranes are prone to perforation and the risk of implant failure increases by 2.19 times when the membrane gets perforated [25, 34]. BPPV occurring during the crestal osteotome technique can be avoided by taking adequate caution during the procedure [63]. Another important complication occurring after the procedure is the acute maxillary sinusitis which when left untreated can cause potential life threatening complications like brain abscess [66, 54].

Conclusion

Implant placement in posterior maxilla is often challenging as the extraction of the first molar results in maxillary sinus pneumatization and reduction of alveolar bone height. To overcome this limitation, elevation of sinus floor with graft placement was attempted by a technique known as Sinus Lifting which facilitates implant placement.

This article reviewed the evidence available for sinus augmentation based on the techniques, materials and associated complications.

On analyzing the treatment modalities used for sinus augmentation, the approach for sinus membrane elevation is determined by the residual alveolar bone height (≥ 5 mm).

Among the various techniques available, the balloon assisted sinus lifting is minimally invasive, safe and simple with less intra operative and post operative complications in both crestal and lateral window approach. With a wide variety of materials available for sinus augmentation ranging from autograft to stem cells, sinus lifting without the use of graft materials is being the current trend. Sinus lift without graft materials is being attempted in both crestal and lateral window techniques due to its advantages like minimal time consumption and reduced cost. It also produces excellent results like 92 to 100 % implant survival rate with bone gain up to 10 mm. Pertaining to graft materials, autograft is the gold standard as always. However with sufficient healing time provided, bone substitutes can be used as an alternative with good clinical outcomes. From analyzing the literature evidence, the use of platelet concentrates for grafting did not produce beneficial effects on implant survival or bone gain. The most common intra operative complication during sinus lift is the membrane perforation which if managed efficiently does not influence the rate of implant survival. Yet another potential intra operative complication is hemorrhage which can be avoided if appropriate pre operative imaging of AAA is done. The common post operative complications include pain, swelling and sinusitis. Effective and timely management of sinusitis is necessary to avoid further potential life threatening complications.

Alternatives to sinus lifting like angulated and short implants are being investigated. Short implants as alternatives for both crestal and lateral sinus lifts produced excellent results with advantages like lesser complications and lesser time.

With increasing demand for replacing missing teeth with dental implants, knowledge about sinus lifting is essential for rehabilitation of posterior maxilla. Thus with appropriate selection of case, technique and material, sinus lifting can bring a predictable and successful treatment outcomes for implants in posterior maxilla. Factors to be considered for sinus lifting include clinicians' skill, patients comfort, time and cost for the procedure and graft materials. Evidence based approach for planning and execution for sinus lifting is mandatory to achieve best treatment outcomes and implant success.

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