Original Article

Inclined implants to bypass maxillary sinus versus vertical implants placed after sinus augmentation in rehabilitation of posterior atrophic maxilla.A two-years prospective randomized clinical study

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ABSTRACT

Purpose: The aim of currents randomized clinical trial was to evaluate clinical outcome of inclined implants to bypass maxillary sinus versus vertical implants placed after sinus augmentation in rehabilitation of posterior atrophic maxilla.

Materials and Methods: Twelve patients (6 males, 6 females) with atrophied unilateral posterior edentulous maxillary ridges, at least 4 - 5 mm of bone height present above the maxillary sinus were randomly allocated into 2 groups: 1) control group; included 6 participants who received vertical implants after sinus augmentation (lateral window technique), 2) study group; included 6 participants who received inclined implants to bypass maxillary sinus. All patients received 3 unit fixed metal ceramic screw retained prosthesis 6 months after implant placement. Clinical outcome (pocket depth,implant stability,marginal bone loss, and implant survival) were measured at base line, 6, 12, 24 months after implant loading. In addition, patient satisfaction with treatment was measured for both groups after one month.

Results: Probing depth,implant stability increased significantly from baseline to 12 months for both groups. No significant difference in probing depth,implant stability between 12 and 24 months was noted.Marginal bone loss significantly increased from6to 24 months. Control group recorded significant higher marginal bone loss than study group at all-time intervals.Study group demonstrated significant higher probing depth,implant stability and patient satisfaction with treatment than control group.cumulative survival rate was 95 % and 100 % for control and study groups respectively.

Conclusion: Inclined implants to bypass maxillary sinus is a viable treatment option in rehabilitation of posterior atrophic maxilla compared to vertical implants placed after sinus augmentation as it was associated with favorable clinical outcomes after 2 years. However, it was associated with increased probing depth.

Key Words: Augmentation, Inclined, Sinus bypass, Vertical implant.

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INTRODUCTION

Implant-supported fixed prosthesis is a commonly used method to rehabilitate missing teeth[1]. However, posterior maxillary ridge present a clinical challenge for implant insertion due to inadequate or deficient bone height[2], reduced to bone density, inadequate accessibility and the sinus pneumatization[3]. For several patients, the remaining of vertical bone height is < 8 mm, consequently difficult to place implant of adequate length to support fixed prosthesis in the area posterior to the first premolar[4]. Maxillary sinus augmentation (using crestal approach or lateral window approach) with or without bone graft are commonly used to restore adequate bone height that is required for the placement of implants of adequate length[2, 5] with implant success rate exceeds 90% on the long term follow up[6]. However this technique involves complex surgical procedures, are associated with postoperative complications that may increase patient morbidity, and reluctance to undergo the procedure due to post-operative pain and swelling[7]. Moreover, the treatment cost and time is far more than the usual implant placement without grafting procedures and the procedure requires a skillful operator[2, 8]. Furthermore, the technique is associated with high incidence of complications such as infection, tearing/perforation of sinus membrane, failure of the graft and is complicated by abnormal sinus anatomy[9, 10].

Other treatment alternatives to sinus augmentation have been described. The use of short implant with a length of 8 mm or less 2 - 4 has been reported but is not recommended in sites with reduced bone quality [11]. Another treatment option is to use vertical implant with distal cantilevers, however this may affect the survival rate of the implants, may induce prosthetic complications such as screw loosening, fracture of implants or abutments or bone loss around the distal implants[12]. Another alternative is to insert implant into the tuberosity and the pterygoid process of maxilla[13], however this approach may be complicated by damage of maxillary artery and its branches[14]. More recently, several investigators described

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the use of distal tilted posterior implants that is placed parallel to the anterior wall of the maxillary sinus to bypass the sinus and permit the implant platform to immerge a more posterior position[15- 17]. The distal inclined implant can be fixated in bone pyramid anterior to the sinus which contains no vital structures (no nerves or blood vessels). The support of the prosthesis is extended more posteriorly, and consequently the cantilever length of the fixated procedures is reduced[18]. Although vertical implant placement directs the masticatory load with the long axes of the implant, biomechanical[16] and animal[19] studies showed that the distal implant tilting had no adverse effect on peri-implant bone resorption. The advantages of tilting the distal implants include; the use of longer implant with increased bone to implant contact in minimum volume of remaining bone, avoiding maxillary sinus[15], eliminates the need of bone grafting[20] and invasive surgical procedures (can be used in patients with compromised medical conditions), reduction of the length of the distal prosthesis cantilever[21]. However, the technique requires computer guided surgical stent for accurate implant placement[22].

To the best knowledge of the author, comparison of inclined implants placed in atrophied posterior maxilla without sinus graft to vertically placed implants placed after sinus augmentation was not investigated. Therefore, the aim of this randomized clinical trial was to evaluate the clinical outcome of inclined implants to bypass maxillary sinus versus vertical implants placed after sinus augmentation in rehabilitation of posterior atrophic maxilla.

MATERIALS AND METHODS

Patient enrollment and study design:

This prospective randomized trial was conducted on 12 patients (6 males and 6 females) who were selected from outpatient clinic of the oral and maxillofacial department, mean age= 54.3 years, (range 49 - 61 years). The inclusion criteria are: 1) Unilateral posterior edentulous maxillary ridges (first and second premolars and molars are extracted and canine is present, 2); inadequate bone height for conventional implant placement with at least 4 - 5mm of bone height present above the maxillary sinus and at least 5 mm of buccolingual bone width exists as measured on preoperative cone beam computed tomography (CBCT), 3) good restorative and interarch spaces for the fixed restoration, 4) good physical condition, 5) good oral hygiene and 6) at least 6 months elapsed after last extraction . The exclusion criteria are; 1) systemic diseases that contraindicate implant placement, 2) patients with radiotherapy or chemotherapy, 3) patients with diabetes mellitus, 4) patients underwent immunosuppressive drugs or intravenous bisphosphonates, 5) patients with a history of untreated periodontitis, and 6) patients with bad habits as bruxism or smoking. The study was conducted according to the ethical principles stated in Declaration of Helsinki in the study protocol was approved by the ethical committee of the faculty of dentistry. The objectives of the study were described to all participants before obtaining signed informed consent from each participant. Patients were categorized into 2 blocks according to patient gender. Three males and 3 females were recruited for each group to ensure equal gender distribution between groups. Then each participant was given a number that was enclosed into sealed envelope. Participants numbers were randomly allocated into 2 groups; control group; included 6 participants (3 males and 3 females) who received vertical implants after sinus augmentation (with lateral window technique), study group; included 6 participants (3 males and 3 females) who received inclined implants to bypass maxillary sinus. All participants received fixed screw retained porcelain fused to metal restoration.

Surgical protocol:

For both groups, all participants received oral hygiene instructions and debridement were performed and revealed for seven days prior to surgery. Prophylactic antibiotics (Augmentin, 1gm, tablet form) were prescribed 1 hour before surgery, and the patients were asked to rinse their mouths with chlorhexidine 0.2 % for one minute. Local anesthesia using Articaine HCL 4 % (ArtPharmaDent, 1 : 200,000 epinephrine) was performed.

For control group (Figure 1), sinus augmentation was performed using lateral approach and vertical implants were inserted. Planning of implant position, selection of implant dimensions, identification of maxillary sinus location ad boundaries was made using the CBCT. The plane was used to construct a stereolithographic surgical guide supported by remaining teeth. The guide contains sleeves compatible with the drills of the implant system used. A crestal incision was made from the canine to maxillary tuberosity area, and full thickness mucoperiosteal flap was elevated. The position of lateral window was identified by preoperative CBCT. The preparation of the lateral window and elevation of sinus membrane was performed using Dentium Advanced Sinus Kit (DASK, Dentium, South Korea. The lateral window was prepared using surgical bur with safe cutting and elevation of the sinus membrane was performed using hand elevators of the surgical kit. The sinus cavity below the membrane was packed with scaffold and granular bone grafting material which consisted of mixture of Xenograft (Intergraft, Neobiotech, particle size 0.2 - 1.0 mm, South Korea) and alloplastic material (Osteon II, 30 % hydroxy apatite and 70 % β-tricalcium phosphate, Pore Size : 250 μm, Porosity : 70 %). Each missing tooth was replaced by one implant. Using stereolithographic surgical guide, and computer guided surgical kit (Dentium, south korea), 3 implant osteotomies were prepared using sequential drilling (one in the remaining bone in the area of the first premolar, and 2 in the 4 - 5 mm height of bone above the sinus. In case of reduced bone density, the last drill was omitted to gain sufficient primary stability of

the implants (at least 30 Ncm). Three sandblasted acid etched implants (4.5 x 10 mm, Superline, platform switch design, Dentium, South Korea) were inserted with implant platform leveled to the crest of the ridge. The sinus was loosely packed and overfilled with bone grafting material, and the lateral window was covered with Biodegradable collagen membrane barrier (Dentium, South Korea) . Flaps were closed using interrupted sutures (Vicryl 4.0).

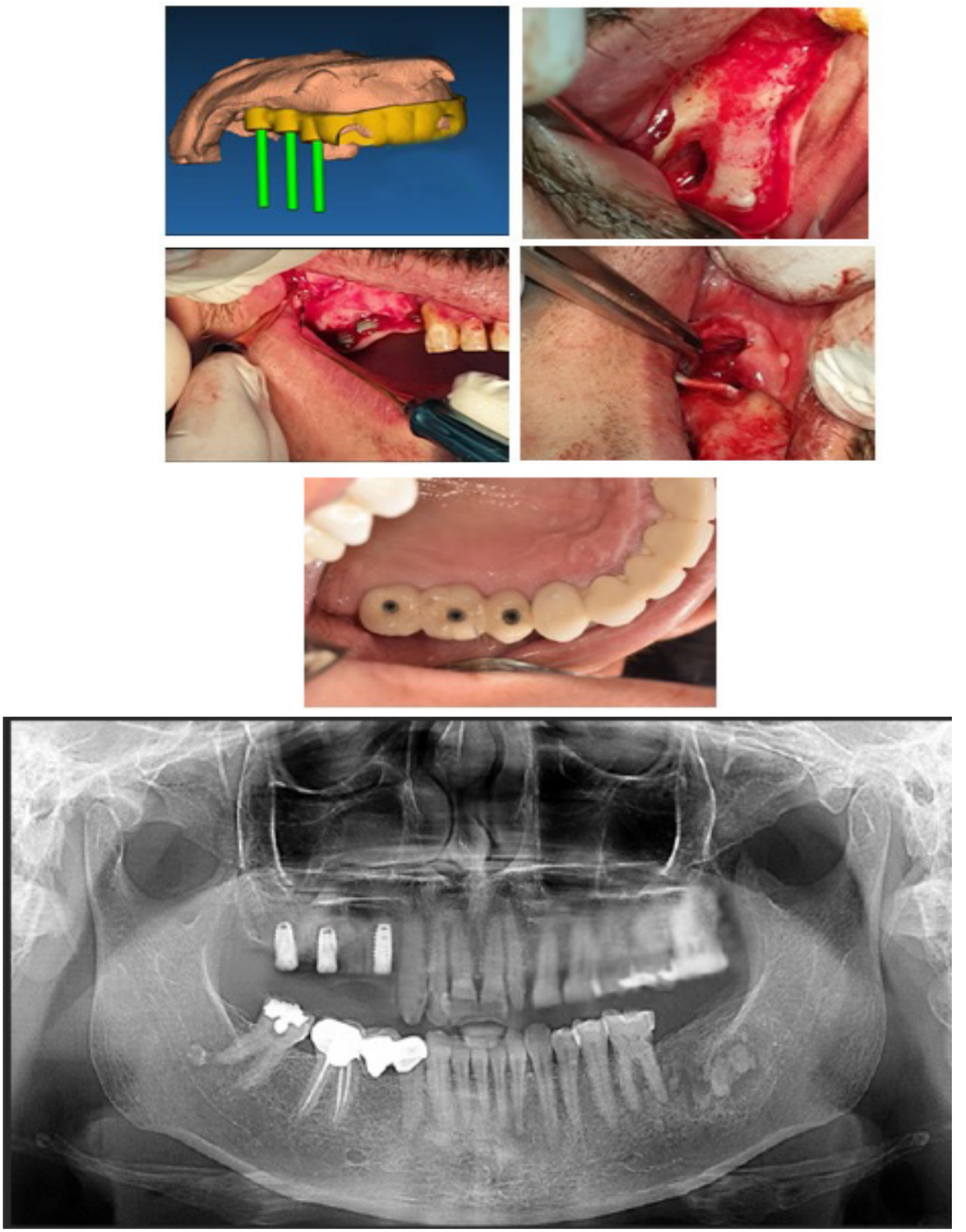

Figure 1: Control group; a) Planning of the sterolithographic surgical guide using the CBCT data, b) preparation of the lateral window, c) implant insertion and packing the window with bone graft, d) covering the bone graft and the window with collagen membrane, e) Screw retained fixed restoration in place, e; Post-operative panoramic radiographs.

For study group (Figure 2) , inclined implants to bypass maxillary sinus without sinus augmentation was performed. Using the CBCT, planning of implant position was made (vertical implant was planned in the first premolar area and inclined implants with 30^0 distal implant angulation (relative to the vertical plane) was positioned just mesial to the anterior wall of the maxillary sinus) in the second premolar and first molar positions. The implant dimensions were selected. The plane was used to construct a sterolithographic surgical guide supported by remaining teeth.

A crestal incision was made from the canine to maxillary tuberosity area, and minimal flap reflection was performed. Two implants only (one vertical and one inclined was used to replace the 2 premolars and the first molar. Using sterolithographic surgical guide, and computer guided surgical kit (Dentium, south korea), 2 implant osteotomies were prepared using sequential drilling (one in the remaining bone in the area of the first premolar, and one just anterior to the maxillary sinus). In case of reduced bone density, the last drill was omitted to gain sufficient primary stability of the implants (at least 30 Ncm). Two sandblasted acid etched implants (44.5-mm in diameter, and 1012-mm in length, Superline, platform switch design, Dentium, South Korea) were inserted (one implant vertical in the area of first premolar and one inclined implant in the area of second premolar and first molar). Countersinking of the posterior implant was made to position the distal portion of the implant platform below the crest of the ridge. The minimum insertion torque of the implants was 35Ncm. Flaps were closed using interrupted sutures (Vicryl 4.0)

Postoperative medications included antibiotics and mouthwash as previously described which continued post-operatively for 7 days (augmentin 1 gm tablets, 2 times per day). In addition, Ibuprofen 400 mg was prescribed two to four times a day for 4 days after surgery. Corticosteroid drugs (Dexamethasone, IM) were prescribed once every 2 days after surgery. Anti-inflammatory medications (Ambezium) were prescribed 2 tablets 2 times daily for 7 days post surgically. Sutures were removed after 10 days. Patients were instructed to use ice packs, eat soft diet for 1 week, and to avoid brushing the surgical sites. If removal appliance was present, the patients were instructed not to wear the appliance for 1 months. The implants were left unloaded for six months until complete Osseointegration and bone formation occurred.

Six months later, Open tray impression was made on the implant level (in control group). In study group, 30o angled multiunit abutment was connected to the tilted implant to correct the implant angulation, and straight multiunit abutment were connected to the vertical implants. Open tray abutment level impression was made. Splinting of the transfer copings was made using a special resin with zero shrinkage (Duralay) to avoid accidental movements of the copings during impression removal. Acrylic jig was constructed for both groups to verify the accuracy of the impression, the passive fit of the restoration and to record the interocclusal relation. Canine guided occlusion was used. For both groups, fixed porcelain fused to metal screw retained restoration was constructed. The prosthesis included 3 artificial teeth (first and second premolar and first molar teeth). Panoramic x-ray was made to ensure complete seating and passive fit of the prosthesis. Instructions for performing adequate oral hygiene and proper cleaning was given to all participants. Regular recall visits were scheduled for all participants for evaluation of peri-implant clinical outcomes.

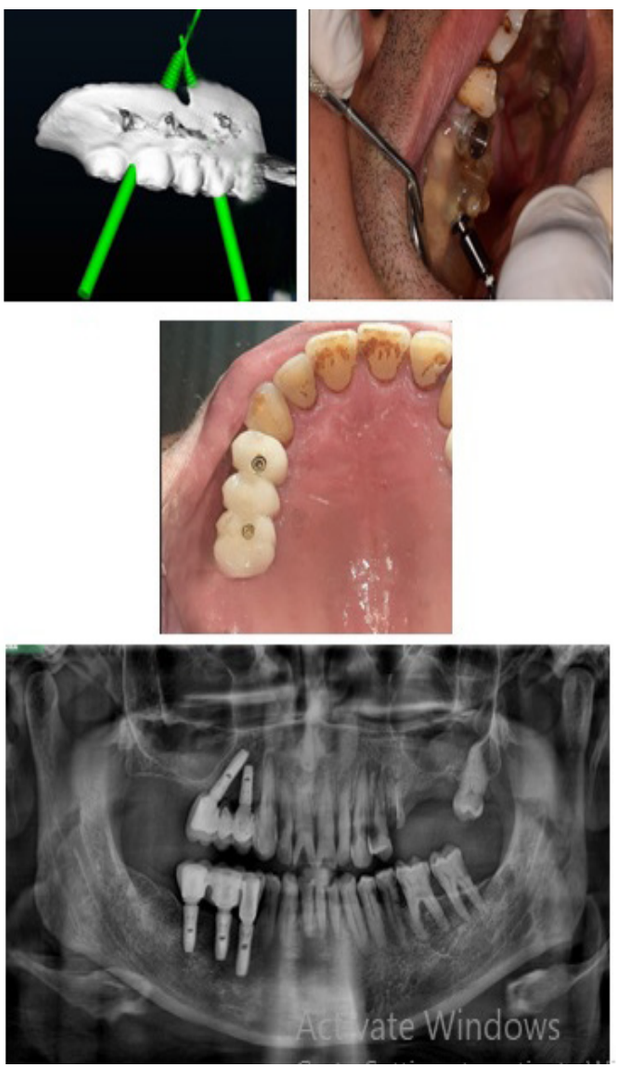

Figure2: Study group; **a)** Planning of the sterolithographic surgical guide using the CBCT data, **b)** implant insertion using the sterolithographic stent and computer guided surgical kit, **c)** Screw retained fixed restoration in place, e; Post-operative panoramic radiographs.

Clinical outcomes:

Clinical outcomes (at patient level) included; pocket depth, implant stability and marginal bone loss which were measured at prosthesis insertion (base line), six months, 12 months, and 24 months later. Measurements were performed by two independent observers to determine the reliability of collected data

Peri- implant pocket depth: Peri- implant pocket depth was measured (PD, in mm) by graduated plastic periodontal probe which inserted in peri-implant gingival Sulcus to measure the distance between free gingival margin and the most apical probing depth23. Measurement was performed at mesial, distal, buccal and lingual surface of each implant, then the mean was used for each implant.

Implant stability: implant stability was measured using resonance frequency analysis (Osstell®, Integration Diagnostics AB, Göteborg, Sweden). The restorations were unscrewed, abutments were removed, smart Pegs were screwed to the internal hex of the implants. The hand piece of the device was held perpendicularly at the smart peg long axis from the buccal direction. Three measurements were performed for each implant and the mean was used.

Marginal bone loss: marginal bone height changes were measured using digital periapical radiographs taken with long cone paralleling technique. A digital radiographic device (Digora, Soredex) with accompanying software was used to acquire digital periapical radiographs. The radiographs were taken perpendicularly to the long axis. A plastic film holder was used to hold the periapical film. For standardization of film position and to maintain the film-implant distance and the cone-implant distance constant during subsequent film exposures, acrylic interocclusal jig was used to hold the film between the teeth. Marginal bone height was measured as the distance between most coronal level of the bone that contacts the implant and the implant platform using image analysis software accompanied the digital radiographic device. Marginal bone loss was calculated as the difference between marginal bone height at the follow-up visits and marginal bone height at baseline. In order to avoid magnification errors, the diameter and length of the implant in the radiographs were compared to the actual diameter and length of the implants to calculate magnification factor. The magnification factor was used to correct the values of apparent bone level to obtain their actual values. Marginal bone height changes were measured at mesial and distal aspect of each implant and the average was used.

Implant survival: Implant survival was calculated according to the method described by Roos et al.24. The implant was considered survived if it fulfilled its proposed function, if no persistent, pain or discomfort was reported, and if no implant mobility was observed.

Patient satisfaction with treatment: Patient satisfaction with treatment was evaluated one month after insertion of the prosthesis18 by independent observer asking the patients about the overall satisfaction with treatment. Three possible answers were provided for each patient; 1) not satisfied with the treatment, 2) medium satisfied with treatment, 3) very satisfied with the treatment.

Statistical Analysis

Shapiro Wilk test was used to determine the normal distribution of the collected data. Descriptive statistics for continuous variables were expressed by mean ± standard deviation. A- Cronbach test was used for data mining interexaminer reliability of the collected data. Comparison of probing depth, implant stability, marginal bone loss between observation times and between groups was performed using Repeated measures analysis of variance (ANOVA), followed by Tukey test for multiple comparisons if significant differences were detected. Comparison of patient satisfaction scores between groups was performed using chi-square test. Cumulative implant survival was demonstrated using life table analysis, and Kaplan-Meier analysis, and the difference in implant survival between group was tested using Log rank test. All data analyses were made using a statistical software (SPSS, version 26.0 ,SPSS Inc., Chicago, IL, USA). The significance level will set at 5%.

Results:

The collected data was reliable with good interexaminer agreement (α chronbach test, correlation coefficient, p>80%). Comparison of clinical outcomes (pocket depth, implant stability and marginal bone loss) between observation times and between groups is presented in table 1. There was a significant difference in implant probing depth between different observation times in both groups (p=.009 for control group and .011 for study group). Probing depths significantly increased from baseline to 24 months in both groups. In both groups, pocket depth significantly increased from baseline to 6 months, then significantly increased the form 6 months to 12 months, however there was no significant difference in pocket depth between 12 months and 24 months. Comparison of pocket depth between groups is presented in table 1. Study group recorded significant higher probing depth than control group at all observation times (p<.032). Comparison of implant stability between observation times revealed a significant difference for both groups (p=.008 for control group and .021 for study group). Implant stability significantly increased from baseline to 24 months in both groups.

Table 1: Comparison of clinical outcomes between observation times and group

	Control group (sinus augmentation) X±SD	**Study group (inclined implant) X±SD**	**Repeated measures ANOVA (*p* value)**
		Probing depth	
At time of loading (baseline)	1.2±.30 a	1.6±.38 a	.003*
6 months after loading	1.6±.38 b	2.2±.39 b	.007*
12 months after loading	2.1±.48 c	2.6±.43 c	.023*
24 months after loading	2.2±.45 c	2.7±.42 c	.031*
Repeated measures ANOVA (*p* value)	.009*	.011*	
		Implant stability	
At time of loading (baseline)	54.62±4.5 a	62.64±3.8 a	.001*
6 months after loading	58.34±3.9 b	64.54±3.2b	.017*
12 months after loading	60.45±3.2c	66.47±3.1 c	.010*
24 months after loading	61.51±2.9 c	66.65±2.8c	.011*
Repeated measures ANOVA (*p* value)	.008*	.021*	
		Marginal bone loss	
At time of loading (baseline)	-	-	
6 months after loading	.85±.28 a	.52±.16 a	.025*
12 months after loading	1.2±.31 b	.93±.29 b	.014*
24 months after loading	1.4±.35 c	1.1±.28 c	.031*
Repeated measures ANOVA (*p* value)	.013*	.021*	

X; mean, SD, standard deviation, different lower case letters in the same column show significant difference between each two observation times (Tukey test, $p<.05$), while the same letter indicates no significant difference. **P* is significant at 0.5

For both groups stability of implant increased from baseline to 6 months, then significantly increased the form 6 months to 12 months, however there was no significant difference in implant stability between 12 months and 24 months. Comparison of implant stability between groups is presented in table 1. Study group recorded significant higher implant stability than control group at all observation times (p<.018). Comparison of peri-implant marginal bone loss between observation times and groups is presented in (table 1). For both groups, there was a significant difference in marginal bone loss between observation times. Marginal bone loss significantly increased with time (p=.013 and .021 for control and study groups respectively). Marginal bone loss significantly increased from 6 months to 12 months, then significantly increased from 12 months to 24 months. Control group demonstrated significant higher bone loss than study group at all observation times (p<0.32). Interval

(Table 2 and Figure 3) showed the cumulative survival rate of implants in both groups over 24 months. Two implant failed in one patient in control group due to infection after sinus augmentation and the failures occurred in the first 6 months after implant placement. The implants were associated with mobility and pus formation. The implants were removed, antibiotics were given to the patient and mucoperiosteal flap was reflected and the site of implant failure was filled with bone graft for future implant placement. However, the patient was excluded from the study, and the data was collected for the rest of the patients in this group according to intention to treat principal. Another implant failed in another patient belongs to control group 6 months after loading. The implant was removed, and the fixed prosthesis was constructed over the remaining 2 implants and the data was collected on patient level for the remaining implants and the patient included in the study. No additional implant this group after six months of loading. No implant failure occurred in the study group. failures occur in

Table 2 : Life table analysis of cumulative survival rate of both groups over 24 months

Group	Interval Start Time	Number Entering Interval	Number Withdrawing during Interval	Number Exposed to Risk	Number of Terminal Events	Proportion Surviving	Cumulative Proportion Surviving at End of Interval
	0	72	16	64.000	2	.97	.97
	6	54	17	45.500	1	.98	.95
Control	12	36	18	27.000	0	1.00	.95
	18	18	0	18.000	0	1.00	.95
	24	18	18	9.000	0	1.00	.95
	0	48	12	42.000	0	1.00	1.00
	6	36	12	30.000	0	1.00	1.00
Study	12	24	12	18.000	0	1.00	1.00
	18	12	0	12.000	0	1.00	1.00
	24	12	12	6.000	0	1.00	1.00

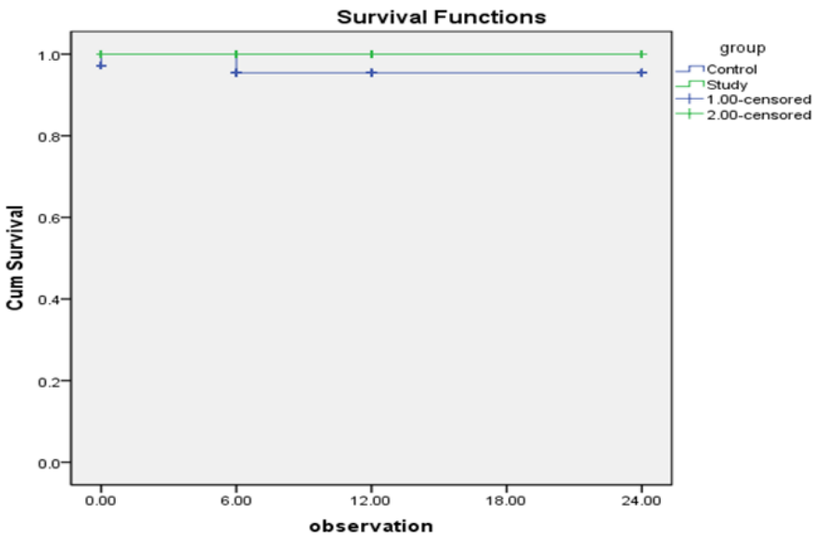

Figure 3 : Kaplan-Meier analysis of survival rate of both groups

The cumulative survival rate was 95% and 100% for control and study groups respectively. No significant difference in implant survival rate between groups were observed (log rank test, p= .156). Comparison of incidence and percentage of patient satisfaction scores between groups is presented in table 3. Two patients (33.3%) in control group and no patients (0%) in the study group were dissatisfied with the treatment. Three patients (50%) in control group and one patients (16.7%) in the study group has medium satisfaction with the treatment. One patient (16.7%) in control group and 5 patients (83.3%) in the study group were very satisfied with the treatment. Study group showed significant higher patient satisfaction with treatment than control group (p=.048).

Table 3: Comparison of patient satisfaction scores between groups

	Not satisfied	**Medium satisfied**	**Very satisfied**
Control (n=6)	2 (33.3%)	3 (50%)	1 (16.7%)
Study (n=6)	0 (0%)	1 (16.7%)	5 (83.3%)
Chi square (p value)		.048*	

DISCUSSION

In this study, the cumulative survival rate was 95% and 100% for control and study groups respectively.

The reduced survival rate of implants in control group (with sinus augmentation) was in line with finding of a previous systematic review[7] in which the authors studied the survival rates for implants placed in the grafted maxillary sinus and found a survival rate ranged from 87.7% to 95.98%.

The high survival rate in the study group was in line with finding of another study18 in which the researchers use an inclined implant anterior to maxillary sinus treatment of atrophied posterior maxilla and found 96.7% cumulative survival rate. However, in the present report the survival rate in the study group was 100%.

The high survival rate in our study may be attributed to the delayed loading protocol of the implants compared to the early functional loading of the implants in the study of Calandriello and Tomatis[18]. Conversely, Calandriello and Tomatis[18] found 2 failures for inclined implants placed anterior to the maxillary sinus and attributed this failure to the crack propagation and fracture of the acrylic provisional bridge used for early loading of the implants.

It is interesting to find that the reduced number of implants (2 implants in the study group compared to 3 implants in control group) had no effect on implant survival rate. This may be due to tilting of posterior implant make them engaging native bone anterior to the maxillary sinus which usually have adequate bone density thus increasing primary implant stability and contributing to high percentage of bone to implant contact and high implant survival rate.

The high survival rate of the inclined implants that bypass maxillary sinus (study group) could suggested that this treatment modality may be a suitable alternative to the conventional sinus augmentation procedures.

Probing depth increased significantly from base line to 12 months for both groups. The increased pocket depth with time may be attributed to the increased peri-implant bone resorption as confirmed in the results of bone loss in this study together with increased peri-implant mucosal enlargement.

The enlargement of thick peri-implant maxillary mucosa may have occurred due to gingival inflammation as a result of plaque accumulation under the prosthesis. The plaque may accumulate due to inability of the patient to clean the prosthesis as the accessibility of posterior maxillary area is difficult for cleaning. However, the increased pocket depth reached a plateau after 12 months.

Study group recorded significant pocket depth than control group at all observation times. A similar observation was noted in other studies[25, 26] for inclined implants supporting “All on four” fixed restorations.

The increased pocket depth in the study group could be attributed to the inclination of posterior implants which necessitate countersinking of these implants below the crest of the alveolar ridge. This countersinking is necessary to place the mesial portion of the implant platform in line with the crest of the ridge and the distal portion below the ridge to prepare what is called “occlusal flare” during osteotomy preparation to accommodate the divergence of the multiunit abutment. This may be due to increased plaque accumulation and gingival enlargement around posterior implant.

Resonance frequency analysis was used to evaluate implant stability as it is noninvasive method that allow verification of implant stability in subsequent evaluations without jeopardizing bone to implant integrity[27]. Implant stability values obtained in all observation times was above 50 indicating stable implants. Implant stability significantly increased from base line to 12 months in both groups. This may be attributed to the increased bone to implant contact along the implant surface as a result of healing and reorganization of bone that increased with time.

Study group recorded significant higher implant stability than control group. A similar observation was also noted in another study for inclined implants bypassing the maxillary sinus [18].

Also the authors reported significant correlation between insertion torque values and the implant stability readings. The increased implant stability for study group may be due to tilting of posterior implant make them engaging native bone anterior to the maxillary sinus which usually have adequate bone density thus increasing primary implant stability and contributing to high percentage of bone to implant as stated previously. In contrast, the bone to implant contact in the control group after sinus augmentation may be compromised or reduced due to the reduced bone quantity and density (quality) of the bone above the maxillary sinuses.

Marginal bone loss was 1.2±.31 and .93±.29 for control and study groups respectively after the first year and 1.4±.35 and 1.1±.28 for control and study groups respectively after the second year.[28] The marginal bone loss values for both groups are located within the normal limit of peri-implant bone loss that is reported in the literature which is not exceed 1.2mm in the first year after loading and increased by 0.2mm annually in subsequent years. 28 Marginal bone loss increased significantly from six months to 24 months for both groups.

This time-dependent bone loss around the implant was reported in several studies and could be attributed to the natural biological process of bone remodeling which occurs after implant placement and immediate bone response to healing and reorganization combined with function stresses of implant loading[29].

A similar observation was noted in another study[30] in which the authors reported implant placed after sinus augmentation gradually lose significant marginal peri-implant bone after one and 3 years of loading.

The marginal bone loss values for study group after one year (.93±.29) were similar to values reported in another study for inclined implant placed anterior to the maxillary sinus[18]. This finding agreed with the results of another biomechanical analysis which found normal peri-implant bone stresses for tilted implants when splinted together with fixed restoration[16].

The marginal bone loss values for control group after one year (1.2±.31) was similar to that obtained in another study[30] for implants placed after sinus augmentation with lateral window approach.

Study group recorded significant lower marginal bone loss than control group. It is well known that placement of implants vertically produces more favorable distribution of stresses in the bone around implants[31] with minimal crestal bone loss[32, 33].

Logically inclined implants may induce bone resorption by nonaxial implant loading as confirm it in invitro studies [34,35,36]. However, clinical studies did not report increased marginal bone loss with inclined implants [37]. Several investigations reported same or less amount of marginal bone loss with inclined implants in comparison to vertical implants [18, 37, 38].

The reduced marginal bone loss in the study group was in agreement with another study[18] who reported that implant tilting per se has no negative effect on bone resorption. Similarly, another study reported that distally tilted implants produced better force transmission than axial implants [39].

Another biomechanical study showed that increasing the tilt of the distal implants does not increase the stress around the implants.40 The reduced marginal bone loss in the study group compared to control group was in line with several clinical studies which reported that peri-implant bone resorption around angulated implants is the same or less as compared to that around the vertical implants [18, 37, 38] The increased bone loss in the control group was in line with finding of another study[30] in which the authors noted that vertical long implants inserted after sinus augmentation lost significantly more peri-implant bone than conventionally placed short implants.

The increased patient satisfaction with treatment in the study group compared to control group may be attributed to the minimal invasiveness of the surgical approach, short healing time, and reduced costs[18]. The increased postoperative pain, discomfort, and edema associated with sinus augmentation may have a negative impact on patient opinion.

Moreover, patients in control group may be under psychological stress and addition of burden of an extra surgery and increased cost[36] which could reduce the patient satisfaction in this group. The other hand, the minimal surgical trauma in the study group together with reduced operation time may be responsible for increased patient satisfaction with this treatment.

The increased patient satisfaction with treatment in the study group compared to control group may be attributed to the minimal invasiveness of the surgical approach, short healing time, and reduced costs18. The increased postoperative pain, discomfort, and edema associated with sinus augmentation may have a negative impact on patient opinion.

Moreover, patients in control group may be under psychological stress and addition of burden of an extra surgery and increased cost36 which could reduce the patient satisfaction in this group. The other hand, the minimal surgical trauma in the study group together with reduced operation time may be responsible for increased patient satisfaction with this treatment.

CONCLUSION

Inclined implants to bypass maxillary sinus is a viable treatment option in the rehabilitation of posterior atrophic maxilla compared to vertical implants placed after sinus augmentation as it was associated with favorable clinical outcomes after 2 years. However, it was associated with increased probing depth.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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