

# Indirect Sinus Floor Elevation for Osseointegrated Prostheses. A 10-Year Prospective Study

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The aim of this study was to evaluate the indirect/closed maxillary floor elevation technique for the insertion of osseointegrated implants to support fixed prostheses clinically. Thirty-one patients (19 female, 12 male) with a mean age of  $62 \pm 9$  years were selected for this study. All patients needed implants in the posterior maxillary region to support osseointegrated prosthesis. Forty-seven implants were inserted using the indirect/closed sinus floor elevation method, and another 31 implants were placed in the same individuals as intra-individual control. No augmentation material was used along with implantation. The mean bone height before sinus lift was  $9.78 \pm 1.68$  mm (minimum 5.6 mm), and for controls it was  $15.62 \pm 3.44$  mm. The average length of the implants used was  $12.00 \pm 1.70$  mm, whereas for controls it was  $13.39 \pm 1.60$  mm. The patients were recalled for periodic checkups every 6 months, and the radiographic controls were made every 12 months. One control fixture failed after uncovering; 77 implants were loaded, and 5 of them failed (2 controls and 3 of the sinus lift group) between 3 and 59 months following loading. One hundred nineteen months after surgery (112 months following loading), the censored survival rate (Kaplan-Meier) was 93.6% for sinus lift implants and 90.3% for controls. The crestal bone level changes were not significant either before loading or after loading for both sinus lift and control implants. None of the remaining implants showed any signs of mobility or peri-implant disease, and none of the patients exhibited sinus problems during the entire observation period.

**Key Words:** sinus elevation, dental implants, survival rate

## INTRODUCTION

Cases of maxillary sinus pneumatization and/or atrophied posterior maxillary ridges cannot support and maintain functioning osseointegrated implants.

Various techniques and materials were proposed to overcome this problem. Autogenous onlay bone grafts,<sup>1-6</sup> guided tissue regeneration,<sup>7-10</sup> and alveolar ridge distraction techniques<sup>11-14</sup> were utilized with concomitant or delayed implant insertion. Different techniques of sinus augmentation were also used.

Two different techniques of sinus augmentation are described in the literature: direct<sup>14-17</sup> and indirect.<sup>15,18-22</sup> The indication for indirect sinus augmentation is a mini-

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 DOI: 10.1563/AAID-JOI-D-09-00085

mum bone thickness of 5 mm underneath the sinus; otherwise, the direct sinus floor augmentation or a 2-stage indirect augmentation technique must be implemented.<sup>22</sup> However, Misch<sup>18</sup> considered that 8 mm subantral bone height is the limit for the indirect sinus augmentation technique, 5–8 mm bone height is indicated for 1-stage direct augmentation with implants, and cases with less than 5 mm bone height are indicated for the 2-stage direct augmentation technique.

Autogenous,<sup>17,23,24</sup> nonautogenous,<sup>25–29</sup> or combination<sup>14,30–34</sup> bone grafting techniques are used for sinus augmentation. Autogenous and combined bone grafting can lead to donor site morbidity and increased surgery time.<sup>32</sup> On the other hand, the reported new bone formation with nonautogenous bone grafting materials varied from 14.7%<sup>29</sup> to 23.1%<sup>25</sup> and from 25% to 27%.<sup>28</sup>

The direct sinus floor augmentation technique has several disadvantages: the blood supply of the alveolar crest may be severely reduced,<sup>35</sup> and an increased possibility of sinus membrane perforation exists that compromises the grafting procedures.<sup>17</sup> As a result of sinus membrane perforation and migration of the graft material, persistent chronic sinusitis may develop.<sup>36–39</sup>

On the other hand, the complications with the indirect sinus elevation technique are less than those of the direct method because it is less invasive.<sup>21</sup> However, the bone augmentation gained by this technique is usually less than that gained by the direct method.<sup>32</sup> The possibility of Schneiderian membrane tearing with subsequent sinusitis and risk of failure is also present.<sup>21</sup>

Several longitudinal studies on sinus augmentation with osseointegrated implants and prosthetic loading were published,\* but most of these studies dealt with the direct technique for sinus augmentation.

\*References 17, 23, 24, 30, 31, 33, 34, 40–43.

### ***Aim of the study***

The aim of this study was to evaluate the indirect method of maxillary sinus floor augmentation for osseointegrated implants without bone grafting. This study tried to find out under intra-individual control whether the implants inserted with indirect sinus elevation have different failure rate, bone level changes, or mobility compared with those inserted using a standard technique.

### **MATERIALS AND METHODS**

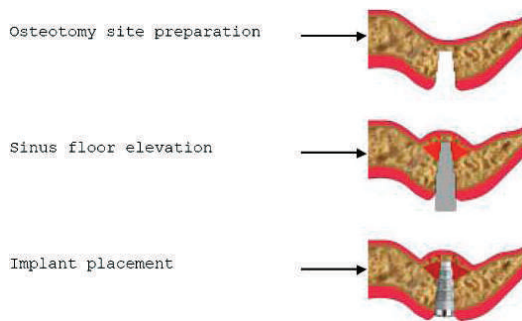
Thirty-one patients (19 female, 12 male; mean age  $62 \pm 9$  years) free from diseases or habits affecting osseointegration were selected for this study. All of them received osseointegrated implants to support fixed prostheses in the lateral maxillae. They had natural mandibular teeth or a fully restored mandibular arch with fixed prostheses. Every patient received at least 2 implants (Friadent, Type 45-03xx, Friadent GmbH, Mannheim, Germany). To act as a control, one fixture was placed using standard technique and one or more implants were placed with indirect/closed sinus floor elevation (CSE).

#### ***Closed sinus elevation technique***

A modified Tatum technique was utilized without bone grafting material.<sup>14</sup> The implant osteotomy sites were prepared to be 1–2 mm beneath the sinus floor. A specially designed bone condenser (Friadent, D 3.0) was used to greenstick fracture and to elevate the floor with its mucosal lining attached to it to the desired level. The implant was then tapped to position (Figure 1).

#### ***Clinical evaluation***

The study was an intra-individual controlled study. After collecting the essential data about the implants, they were divided into 2 groups based on the technique of placement: group 1 consisted of 47 implants inserted with closed sinus elevation method;



**FIGURE 1.** Closed sinus floor elevation for implants.

group 2 consisted of 31 implants inserted according to the standard technique of implant insertion.

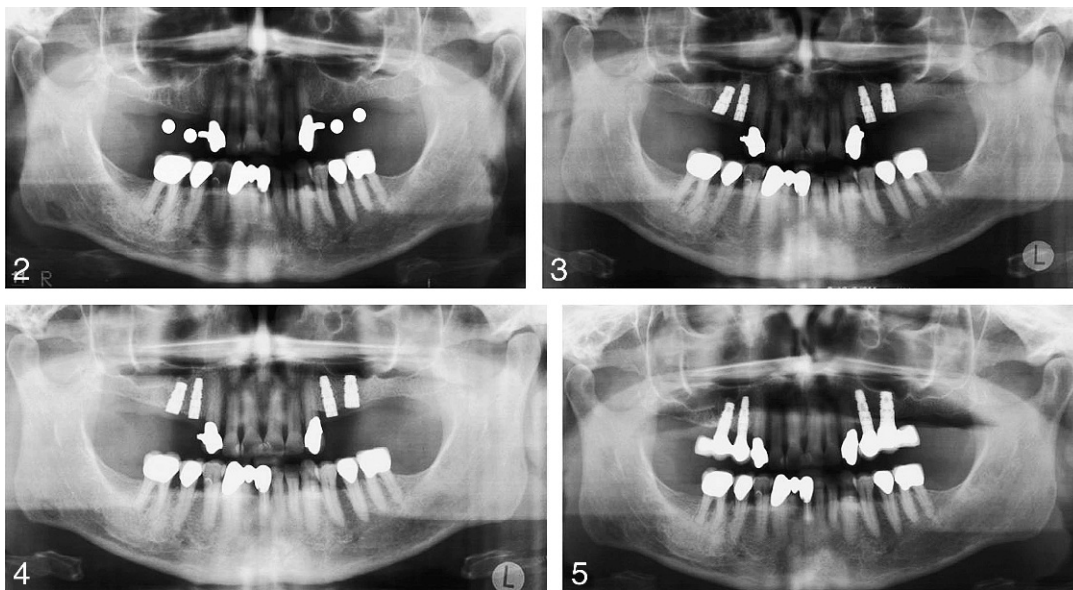
The selected patients had either bone density D3 or D4. Bone height before augmentation was measured from a calibrated presurgery orthopantomogram (OPG) (Figure 2). The average bone height before augmentation was  $9.82 \pm 1.53$  mm for the CSE group (minimum 5.6 mm), and  $15.50 \pm 2.30$  mm for the control group (minimum 11 mm). The average length of the implants used was  $12.00 \pm 1.70$  mm for the CSE group, and  $13.39 \pm 1.60$  mm for the control group. The healing period for D3 im-

plants was  $8.8 \pm 3.8$  months (minimum 3 months). For the D4 implants the healing period was  $9.8 \pm 4.8$  months (minimum 4 months).

Clinical evaluation was carried out every 6 months after prosthetic loading for a minimum of 2 years. The implants in both groups were observed for presence of mobility by alternate application of slight pressure on the abutment by 2 hand instruments. The implants were scored to be not mobile or mobile (grade 0 or >0). Any sign of gingival inflammation in the peri-implant region such as redness or bleeding was also recorded.

### **Radiographic evaluation**

Immediate postsurgery OPGs were considered as a reference for the bone level beneath the implants (ie, first measurement radiograph) (Figure 3). OPGs taken directly before loading and OPGs taken 24 months after loading were considered as the second and third measurement radiographs, respectively (Figures 4 and 5). The bone height



**FIGURES 2-5.** **FIGURE 2.** Preoperative orthopantomogram (OPG) with metallic balls to calibrate magnifications. **FIGURE 3.** Immediate postoperative OPG to act as a reference for bone height beneath the implant. **FIGURE 4.** Preloading OPG to measure bone height changes around the implants before loading. **FIGURE 5.** OPG 24 months after loading to measure bone height changes around the implants.

around the implants was evaluated at the following sites: apical to the implants of group 1 (CSE), and mesial and distal surfaces at the crestal bone level around the implants of both groups. Each measurement was repeated 3 times, and the average was used in the statistical comparison.

The bone level apical to the implants of CSE group was measured from the apex of the implant to the apical most point of bone above it. The crestal bone level was measured from the crest of the ridge to the implant apex mesially and distally for both groups. To obtain the actual values, the magnification factor for each radiograph was calculated taking the corresponding implant as a reference (metallic object of known length). The differences between each radiograph and its successive radiograph were calculated for all implants and statistically compared. The area of osseointegration around each implant was calculated using the equation:  $A = \pi \cdot r^2 \cdot l$ , whereby  $A$  is the area of osseointegration,  $\pi = 3.14$ ,  $r$  is the average radius of the implant, and  $l$  is the implant length surrounded by bone.

Statistical comparisons were carried out using the StatView program (Abacus Concepts Inc, Berkeley, Calif). The survival rate was calculated for the whole period of follow up (about 10 years) using the Kaplan-Meier cumulative survival test. Both the surgical and prosthetic hazards were included in the results, whereas the bone level changes beneath the implants were calculated for the period of postloading evaluation (2 years). Multiple-level analysis of variance (ANOVA) tests were used to compare the peri-implant bone level changes in both groups before and after loading.

## RESULTS

### *Implant failure and clinical picture*

In the control group, 31 implants were placed, 1 implant failed before loading at

11 months after surgery in a female patient with bone density class D4 (left second molar area), diameter 3.8 mm, length 13 mm, opposed by natural teeth, and the presurgery bone height estimated at 14 mm. Another 2 implants failed after 20 months (female, D3, diameter 3.8 mm, length 15 mm, region left second premolar, opposed by a fixed bridge, estimated bone height 16.40 mm) and 59 months after loading (male, D3, diameter 3.8 mm, length 11 mm, region left first molar, opposed by natural teeth, estimated bone height 12 mm).

In the CSE group, 47 implants were placed. Three implants failed after loading at 2 months (female, D3, diameter 3.8 mm, length 13 mm, left second premolar, opposed by a fixed bridge, estimated bone height 11 mm), at 3 months (female, D3, diameter 3.8 mm, length 11 mm, left second premolar, opposed by a fixed bridge, estimated bone height 10 mm), and at 46 months after loading (male, D3, diameter 5.5 mm, length 10 mm, right first molar, opposed by natural teeth, estimated bone height 7 mm). Implant failures were found to be independent of the method of treatment, whether CSE or control ( $\chi^2 = 0.29$ ,  $P = .59$ ).

The remaining 72 implants exhibited no mobility or peri-implant disease and revealed undisturbed function during the entire period of observation. Sinus problems were seen neither for lost nor for remaining implants during the entire observation period.

### *Cumulative survival of the implants*

The cumulative survival rate of the implants was calculated for both groups by the Kaplan-Meier method. One hundred nineteen months after surgery or 112 months after prosthetic loading, the cumulative survival rate for the control implants was 90.3%, while for the CSE implants it was 93.6%. No statistical difference was seen

	Observations, N	Events, N	Censored, N	Censored, %
Control	31	3	28	90.3
CSE	47	3	44	93.6
Total	78	6	72	92.3

\*Sensor variable: implant loss; grouping variable: closed sinus elevation (CSE).

between the two groups ( $P = .80$ ) (Table 1; Figure 6).

### Bone level changes around the implants

#### Apical Aspect Around CSE Implants

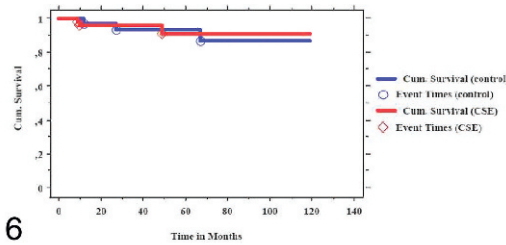
The average amount of sinus floor elevation was 2.95 mm. The mean increase of the apical bone thickness in CSE implants was  $1.85 \pm 1.1$  mm.

#### Mesial and Distal Bone Level Changes

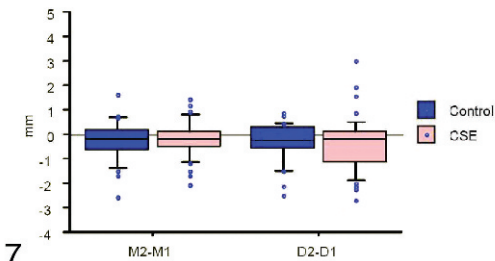
The average crestal bone levels around the implants in both groups are presented in Tables 2a and 2b. The crestal bone level changes around the implants were not significant either before or after loading for both CSE and control implants. Those differences were also insignificant between the mesial and distal sites as well as between the two groups ( $P > .05$ ) (Figures 7 and 8; Table 3).

#### Relation Between Crestal Bone Loss Around the Implants, and the Different Variables

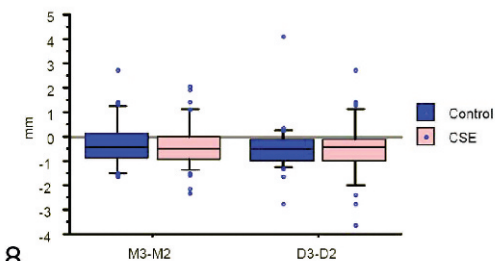
ANOVA testing was conducted to detect the possible relation between crestal bone level changes around the implants and the technique of implantation, presurgery bone height, area of osseointegration, and their interactions. The differences between postloading and preloading crestal bone levels at the mesial and distal sides of the implants were used in this test. The crestal bone level changes 24 months after loading were found to be independent of the technique of implantation, presurgery bone height, or



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**FIGURES 6-8.** **FIGURE 6.** Kaplan-Meier cumulative survival plot for implants in both groups: Sensor variable, implant loss; grouping variable, closed sinus elevation (CSE). **FIGURE 7.** Marginal bone level changes before prosthetic loading of the implants. M1/D1 indicates mesial/distal bone level at placement stage; M2/D2, mesial/distal bone level at beginning of loading; M2-M1, preloading crestal bone level changes at the mesial side of the implant; D2-D1, preloading crestal bone level changes at the distal side of the implant. **FIGURE 8.** Marginal bone level changes 24 months after prosthetic loading of the implants. M2/D2 indicates mesial/distal bone level at beginning of loading; M3/D3, mesial/distal bone level after 24 months of loading; M3-M2, postloading crestal bone level changes at the mesial side of the implant; D3-D2, postloading crestal bone level changes at the distal side of the implant.



Average crestal bone levels at the mesial side of the implants in both groups (in mm)*						
	M1		M2		M3	
	Control	CSE	Control	CSE	Control	CSE
Mean $\pm$ SD	11.71 $\pm$ 1.73	10.40 $\pm$ 1.84	11.45 $\pm$ 2.08	10.17 $\pm$ 1.99	11.19 $\pm$ 1.92	9.80 $\pm$ 1.88

\*M1 indicates postoperative bone level; M2, preloading bone level; M3, bone level 24 months after loading; CSE, closed sinus floor elevation.

area of osseointegration. *P* values are presented in Table 4.

### DISCUSSION

The present study evaluated the closed sinus floor elevation method without the use of any bone graft or bone augmentation material. Two implant groups with intra-individual control were followed up for a minimum of 2 years loading period. This control method eliminated the variables of patient sex, age, and bone density. These variables, however, were found in previous studies to have insignificant relation to implant success or failure.<sup>44</sup>

The applied CSE method was suggested by Tatum in the late 1970s<sup>14</sup> as one of a variety of techniques for sinus floor elevations. He suggested that sinus elevation may be carried out without any bone augmentation. Such a situation was not reported in a clinical study. Autogenous bone grafting had its drawbacks, whereas the results of non-autogenous bone grafting are conflicting.<sup>25,28,29</sup> Moreover, ultrasonographic and endoscopic evaluation revealed that the cause of postoperative sinusitis is the migra-

tion of the graft material.<sup>33,34</sup> This explains the absence of chronic sinusitis in our study group.

The type of supported prostheses as well as the type of opposing dentition affect the total load delivered to the implant and can play a significant role in implant success or failure.<sup>45,46</sup> Implants placed in areas of more spongy bone need a longer healing period than implants placed in less spongy bone and must be gradually loaded.<sup>47</sup> In the present study the implants were inserted in bone quality of class D3 or D4. Those implants inserted in areas of D4 bone density were given a longer healing period and were loaded gradually to assure osseointegration. Moreover, the implants of both groups were loaded by fixed prostheses and opposed by either a full set of natural teeth or a full restored mandibular arch by fixed prostheses. Such loading conditions are more or less the same and eliminate a variable that affects to a great extent the implant success.

Both timing and method of evaluation (OPGs) used in our study are in agreement with the literature.<sup>17,23,24,30</sup> In the reported studies on sinus augmentation, the majority of

Average crestal bone levels at the distal side of the implants in both groups (in mm)*						
	D1		D2		D3	
	Control	CSE	Control	CSE	Control	CSE
Mean $\pm$ SD	11.86 $\pm$ 1.63	9.98 $\pm$ 2.16	11.51 $\pm$ 1.94	9.62 $\pm$ 2.27	11.07 $\pm$ 1.87	9.15 $\pm$ 1.92

\*D1 indicates postoperative bone level; D2, preloading bone level; D3, bone level 24 months after loading; CSE, closed sinus floor elevation.

TABLE 3  
Marginal bone level changes around the implants in both groups (in mm)\*

	M2-M1		D2-D1		M3-M2		D3-D2	
	Control	CSE	Control	CSE	Control	CSE	Control	CSE
Mean ± SD	-0.26 ± 0.83	-0.23 ± 0.73	-0.35 ± 0.82	-0.35 ± 1.09	-0.26 ± 1.01	-0.38 ± 0.95	-0.44 ± 1.12	-0.47 ± 1.17
P value	.87		.99		.64		.90	

\*M1/D1 indicates mesial/distal bone level at placement stage; M2/D2, mesial/distal bone level at beginning of loading; M3/D3, mesial/distal bone level after 24 months of loading; CSE, closed sinus floor elevation.

failures as well as the great percentage of bone level changes were found to occur during the first 2 years of loading.<sup>17,22-25,28-34,40-43</sup>

The cumulative survival rate in this study is in agreement with the results found in the literature.<sup>24,31,42,43</sup> The CSE implants showed a slightly higher cumulative survival rate than the control. However, the difference was not statistically significant. This is due to the intra-individual control that eliminated the factors of rate of healing and host response.

All the remaining implants showed no mobility. Implant mobility is an important sign of failure and is due to infection, impaired healing, and overload. Delayed implant mobility can be caused by a combination of poor bone quality, mechanical trauma to bone, and overloading forces.<sup>48</sup> The load delivered to the implant is an important factor for success. Masticatory and permanent loading leads to functional osseointegration, and implants

can tolerate axial or horizontal loading due to the absence of periodontal membrane.<sup>47</sup> However, inclined loading of an implant leads to development of compressive stress adjacent to the side of loading, and tensile stress at the other side. This condition will lead to microcracks in bone, implant looseness, and failure.<sup>49</sup> An extrusion component of load may develop at the maxillary canine or premolar implants due to analysis of force as a result of deep guidance in lateral excursions. Such a condition was avoided during prosthetic management of the implants in both groups.

The bone gain apical to the implants in the CSE group is in accordance with the results of Peleg et al.<sup>41</sup> It is also supported by the findings of Boyne and James<sup>16</sup> that the mere elevation of the Schneiderian membrane results in a certain amount of bone formation. However, it is difficult to judge whether this bone gain is 3-dimensional or

TABLE 4  
P values for a possible effect between crestal bone loss, technique of implantation, area of osseointegration around the implant, and presurgery bone height\*

Factors Tested by Multiple Level ANOVA	P Values	
	M1-M3	D1-D3
Closed sinus elevation (CSE)	.75	.43
Osseointegration area (OA)	.70	.15
Preoperative bone height (BH)	.98	.33
CSE vs OA	.85	.24
CSE vs BH	.90	.35
OA vs BH	.83	.15
CSE vs OA vs BH	.99	.17

\*M1/D1 indicates mesial/distal bone level at placement stage; M2/D2, mesial/distal bone level at beginning of loading; M3/D3, mesial/distal bone level after 24 months of loading.

not. The method of evaluation in this study was a radiographic one that gives only 2-dimensional pictures.

The bone level changes around the implants were not significantly different between the 2 groups of implants. They were not dependent on area of osseointegration or preoperative bone level. This is again due to the intra-individual control and the similarity in loading condition.

### CONCLUSION

The indirect/closed sinus lift method is an effective and less complicated method for the placement of osseointegrated implants in moderately atrophied ridges of the posterior maxilla.

### ABBREVIATIONS

ANOVA: analysis of variance  
BH: bone height  
CSE: closed sinus floor elevation  
OA: osseointegration area  
OPG: orthopantomogram

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