SINUS FLOOR ELEVATION: COMPARISON OF THE PRESURGICAL RIDGE HEIGHT OF DIFFERENT TECHNIQUES - A RETROSPECTIVE ANALYSIS.

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ABSTRACT

Purpose: Radiographic evaluation of the vertical presurgical ridge height (PRH) of implants, placed using the transcrestal or lateral window sinus floor elevation (SFE) technique in edentulous and partially dentate patients. The 5-year implant survival rate and the prosthetic restoration following the SFE procedure were also evaluated.

Methods: Radiographs of 83 tapered implants placed in 53 patients were available for analysis. 31 implants were placed by the transcrestal and 52 were placed by the lateral window technique. In the lateral window technique 21 implants were placed simultaneously, 31 in a staged approach. The PRH, the implant survival rate after five years and the prosthetic restoration were evaluated with respect to the chosen SFE procedure.

Results: The PRH was significantly higher for the transcrestal than both lateral window techniques, mean values: 8.0 ± 2.7 mm (transcrestal); 4.2 ± 2.6 mm (lateral simultaneous); 4.5 ± 2.8 mm (lateral staged). There was no significant difference of PRH between the edentulous and partially dentate patients. All loaded implants were stable, resulting in a 100% implant survival rate after 5 years. There was a small overproportion of single crown restorations in the transcrestal SFE technique group.

Conclusion: This study confirms that the transcrestal technique is chosen, when a higher PRH is available. The choice of a simultaneous or staged lateral window approach is mainly dependent on the expected primary stability of the implant and not only on the PRH. SFE procedures are a safe and predictable treatment option to place implants in the vertical atrophic maxilla.

Keywords:

sinus floor elevation, transcrestal technique, lateral window technique, presurgical ridge height, prosthetic restoration.

Introduction

In the posterior maxilla the individual anatomy and the volume of the sinus may lead to a reduced amount of bone available for the placement of implants. The alveolar remodeling process that follows tooth extraction may result in up to a 50% reduction in the surrounding bone width within the first 12 months[1], which progresses further in individual extent [2, 3]. This bone remodeling process results in absolute vertical and horizontal ridge resorption. Eventually, various techniques were developed to improve the surgical site for the placement of implants. For example, sinus grafting enables implant placement in the posterior maxilla of partially or completely edentulous patients[4]. Various sinus floor elevation (SFE) procedures have been described and clinically applied, and they appear to be successful [5, 6].

The idea of maxillary sinus floor elevation goes back to the work of Tatum in 1976/77. The surgical technique was published in the 1980's [7, 8]. Since the first description of sinus elevation, numerous articles have been published comparing different techniques and different grafting materials [9-16].

The transalveolar osteotome technique with simultaneous implant placement was introduced as a less invasive and simpler alternative method[16-21]. The advantages of this minimally invasive technique are reduced patient morbidity and decreased treatment time and cost. There is contradictory information in the literature regarding the required presurgical ridge height (PRH) in relation to the sinus floor elevation technique. Some authors described the transalveolar technique in areas with a ridge height of 3 mm[22, 23] whereas others described a ridge height of more than 9 mm [24, 25]. It is discussed whether the PRH influences the long-term survival rate of the implants. Rosen et al. found that a smaller PRH influences negatively the long-term survival rate of the implants [23].

More over the literature concerning the lateral window technique, which is performed either before or at the same time as the implant placement [26, 27] is not conclusive. 4 mm is discussed as a cut-off PRH by various authors. A ridge height of more than 4mm allows carrying out a simultaneous implant placement procedure, for a ridge height below 4mm a staged implant placement procedure is recommended [28-30]. An alternative criterion for the application of a simultaneous procedure is the likelihood of achieving primary implant stability. This is a subjective criterion that may vary between different surgeons.

In one study cases with a simultaneous procedure and a PRH of less than 5 mm showed a lower implant survival rate, if the healing period was less than 9 months [31].

The diagnosis of localized ridge atrophy is based on both clinical examination and radiographic findings. Most studies investigating PRH are based on two-dimensional radiographic findings. Because a healthy, well-structured mucosa can clinically disguise an atrophic jawbone in the pre-implant diagnosis [32], new radiographic technologies and computer software are important for producing a 3-D evaluation of the ridge volume and allows when available, more detailed analysis, selection and planning of the SFE procedure.

The currently available studies rarely discuss the choice of prosthetic restorations on implants after application of the various SFE procedures. We assumed that partially dentate patients, especially when they still have teeth in the lateral tooth area, have more residual bone and therefore only require a less extensive SFE procedure, with the transcrestal technique. On the contrary, edentulous patients have a more pronounced ridge atrophy and therefore need a more extensive SFE procedure and greater prosthetic restorations. We analyzed whether the less invasive transcrestal technique was associated to single crowns and the lateral technique to more complex prosthetic restorations, such as bars and full bridges.

The primary endpoint of this retrospective study was the radiographic analysis of the PRH in relation to the chosen SFE procedure. The secondary endpoint was the comparison of the radiographic visibility of the graft material of the different (transcrestal/lateral) SFE procedures. Additionally the survival rate of the implants analyzed and the type of prosthetic restoration in relation to the applied SFE procedure was identified.

Materials and Methods

Patients / Implants

All patients who were treated with a SFE procedure at the Department of Prosthodontics, University of Bern during the years 2006 and 2007 were included in the present study.

Inclusion criteria were:

Presence of maxillary unilateral or bilateral edentulism involving the premolar and/or molar area; adequate treatment plan for prosthetic rehabilitation including oral implants; required minimum length of 10 mm for the implants to be placed; age >20 years and good general health.

Exclusion criteria were:

Recent sinusitis and history of surgical procedures in the sinus region; radiographically unclear structures in the sinus that may indicate some pathological process; severe health problems such as a history of heart attack within the last six months, uncontrolled or insulin-dependent diabetes; irradiation or chemotherapy; any health condition that would compromise a surgical procedure under local anesthesia; psychiatric problems, drug and alcohol abuse; severe parafunctional habits and heavy smoking. Patients who refused to have extensive surgery or who were not willing to have surgery for financial reasons were excluded from the study.

For interested and compliant patients, a smoking cessation protocol was performed prior to treatment.

All patients were informed in detail regarding the SFE and implant placement procedures before they signed the informed consent form. The data collection for the present study was performed strictly anonymously and was based on an abstraction of the oral examinations, radiographs and medical files. This retrospective survey

was part of a quality control assessment of the dental consultation and was performed in compliance with good clinical practice according to the Declaration of Helsinki. All implants placed in this study were Replace Select Tapered™ implants (Nobel Biocare, Gothenburg, Sweden) of a length of 10mm or 13 mm.

Treatment planning / Surgical approach

Partially edentulous patients where planned to receive single crowns and fixed partial prosthesis by exclusive implant support or removable partial prostheses by combined tooth and implant support. Edentulous patients were planned to receive implant overdentures on single attachments or bars or full fixed implant prosthesis.

Treatment planning included (mounted) casts, a prosthetic set-up to simulate the prosthetic treatment outcome and fabrication of radiographic and surgical splints. Radiographs taken with the paralleling technique were used in partially dentate patients, while orthopantomograms were used in edentulous patients. The radiographs were taken with splints including metallic markers of known size to measure the presurgical ridge height (PRH) and to plan for implant placement. This planning included an analysis of the prospective implant position in relation to the topography of the sinus floor, any adjacent teeth and the desired tooth set up.

For all enrolled patients, the surgical treatment was performed in a university setting and under the supervision of the same instructor. The surgical procedure was conducted under local anesthesia and antibiotics were administered 1 hour preoperatively and for the 5 days following surgery. Deproteinized bovine bone matrix (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) was used as the grafting material [33-36].

Sinus floor elevation (SFE) Procedures:

1) Transcrestal SFE technique

A set of specific osteotome instruments was available for use with tapered implants (Nobel Biocare, Gothenburg, Sweden). After incision of the mucosa, a mucoperiostal flap was raised. Guided by the surgical splint, the initial access into the ridge bone was achieved with a small drill. Using the pilot drill (diameter 2 mm), a hole was prepared with a penetration depth that was 2 mm shorter than the measured PRH. Then the hole was penetrated with the spreading and tapping instruments according to the manufacturers' guidelines until the sinus floor was fractured. A nurse held the patient's head during the tapping procedure [37]. Small amounts of Bio-Oss® particles (Geistlich Pharma AG, Wolhusen, Switzerland) were gradually pushed into the sinus, and the implant was then inserted without further preparation of the implant bed. Good primary implant stability was required for successful placement and was measured with the RFA (Resonance Frequency Analysis)[38]. The flap was then sutured with the implant submerged, and the sutures were removed after 8 days. An undisturbed healing phase of 4 months was maintained before the prosthetic treatment was performed.

2) Lateral window technique (simultaneous or staged approach)

According to the prospective position of the implant(s) as given by the surgical splint, a crestal incision with lateral releases was performed and the mucoperiostal flap was raised to expose the lateral wall of the sinus. A rectangular window was prepared with a diamond bur, and after this preparation a special set of instruments (Hu-Friedy, Leimen, Germany) was used to create the space in the sinus. In two cases, visible rupture of the Schneiderian membrane occurred. In these cases, to protect the sinus, the prospective space was re-lined with a resorbable porcine collagen membrane (BioGide®, Geistlich Pharma AG, Wolhusen, Switzerland). The cortical bone was not completely removed from the window, as it served as a stable base when lifting the membrane. In the simultaneous approach, the implant-bed was prepared through minimal and careful drilling. Subsequently, the implant was placed, and the Bio-Oss® (Geistlich Pharma AG, Wolhusen, Switzerland) graft material was mixed with fresh blood from the wound and packed into the lumen around the implant. The elevated and grafted area was then covered with a BioGide® membrane and the mucoperiostal flap was sutured. Primary stability of the implant was tested manually and with RFA measurement [39]. 10 days after the surgery the sutures were removed. If the patients had to wear a provisional denture, the denture flange above the buccal window was completely removed to avoid any pressure or trauma to the surgical site. A healing phase of 6 months was maintained before the re-entry surgery was performed, and the prosthetic treatment was initiated.

A staged approach was chosen in cases where no primary implant stability was expected or bone with a loose structure that would not support the stability of the implants. The sinus was grafted as described before, and after a healing period of 6 months, the implants were placed in a second surgical intervention. The healing period following the implant placement was 3 months.

Data collection and radiographic analysis

After prosthetic rehabilitation, all patients followed a regular maintenance care program with at least one, and mostly two, scheduled sessions per year. The dental hygienist checked hygiene, recorded probing depths and performed professional cleaning of the implants. If bleeding on probing or insufficient hygiene was recorded, the patients received closely supervised hygienic monitoring with over short intervals. The dentist monitored any problems with the implants, components, anchorage devices and prostheses. Initially, conventional orthoradial radiographs were taken for all patients for treatment planning purposes, after the surgical procedures and after completion of the prosthetic rehabilitation. The earlier radiographs were recorded on film, which were easily readable. These radiographs were subsequently digitized, and all 5-year radiographs were taken in digital form. A single investigator, not involved in the patient's treatment, was trained by a supervising investigator and conducted all the measurements. Any ambiguous situations were double checked by the supervisor.

Radiographic monitoring was performed 1, 2 and 5 years after surgery for every patient, or earlier if specific problems were assumed or discovered. All measurements were carried out on the 5 year follow-up radiograph. The initial ridge height was traced from the radiograph taken prior to surgery. The original sinus floor was identified and marked. The known implant length was used to calibrate the measurements. The radiographs were analyzed using Dimaxis Pro software (version 4.3.2 Planmeca, Finland).

The PRH was measured in mm. The PRH was assigned to the chosen SFE procedure. The radiological visibility of the graft material around the implant apex was determined and classified as slightly visible, well visible or strongly visible. Figures 1) to 2b) show the measuring methods.

Statistical analysis

Descriptive statistics, including the mean values and standard deviation (SD), were used to characterize radiographic PRH, the visibility of the graft material, the patient demographics, implant distribution and prosthetic restorations. The nonparametric Kruskal-Wallis test and Mann-Whitney U-test were used to detect differences between the SFE techniques. The significance level was set at $p < 0.05$. SPSS software (SPSS 18.0, Chicago, IL, USA) was used for the analysis.

Results

Originally 86 implants were planned in a total of 54 patients. Following cases were not included in the data: One patient with a single implant placed using the transcrestal SFE technique passed away from natural causes and was therefore unavailable for the five-year follow-up appointment. A single implant placed using the transcrestal SFE technique failed (PRH = 8 mm); it was found to be mobile while impressions were being taken, and it was neither loaded nor replaced. Another implant was not placed as planned in the lateral staged approach because of loose graft material. Therefore data from a total of 52 patients (27 female and 25 male, with a mean age of 62 ±12 years at the time of implant placement) were analyzed. 83 implants with a length of 10 mm (54%) and 13 mm (46%) were placed using the SFE procedures; 36 partially maxillary dentate patients had 45 implants placed, and 16 maxillary edentulous patients had 39 implants placed. 91 additional implants, not in contact with the sinus, were also installed to support the planned prostheses (not part of the statistical analysis). In total, 54 prostheses (33 fixed, 21 removable) were used in this study. Table 1 gives an overview of the prosthetic restorations used. The implants placed with a SFE procedure were equally distributed in the positions of the first and second premolar or first molar. All implants were stable and continued to support the original prosthesis after a period of five years.

As shown in Table 2, the average number of implants placed per patient using the SFE procedure was higher (1.9 Implants vs. 1.2 Implants) when a surgical approach was performed with lateral access and when patients had an edentulous maxilla.

The PRH was significantly ($p < 0.05$) higher for the transcrestal than for the lateral techniques. Mean value for the transcrestal techniqe: 8 ± 2.7 mm, mean value for the lateral simultaneous approach: 4.2 ± 2.6 mm, mean value for the lateral staged approach: 4.5 ± 2.8 mm lateral staged. Within the lateral approaches the difference was not statistically significant ($p = 0.24$). The mean values for PRH were not significantly different between edentulous and partially dentate maxillae ($p = 0.18$). Table 3 and Figure 4 give an overview of the PRH of the different SFE procedures.

Visibility of the graft material around the implant apex was higher for the lateral technique: 73% of the implants placed with the lateral window technique were classified as having strong visibility, whereas 39% of the implants placed using the transcrestal SFE technique were classified as slightly visible. The radiological visibility of

the graft material was similar in edentulous and partially dentate patients for all SFE procedures.

A weak trend was found concerning implants restored with single crowns, they were more often placed with the transcrestal SFE technique. 50% of the single crowns were incorporated on implants placed by means of a trancrestal technique, only 38% of all implants using the SFE, were placed with the transcrestal technique.

Discussion

In our data the presurgical maxillary ridge height showed a wide range within the samples of the same sinus floor elevation technique. In the transcrestal technique group the PRH was between 5.3 mm and 10.7 mm. In the lateral window technique groups, the range within cases with a staged approach was from 1.7 mm to 7.3 mm, in cases with a simultaneous approach from 1.8 mm to 7.3 mm. The mean value for the PRH in the present study for the transcrestal technique is similar (8 mm) to earlier studies [24, 25, 40].

In most studies, the selection of a staged or a simultaneous approach within the lateral window technique depends on the PRH. A PRH of 4 mm is discussed as the cut-off amount for this decision; early studies from the 1990s suggest a staged approach if the PRH is between 3 and 4 mm and a simultaneous approach if the PRH is between 4 to 6 mm and primary implant stability can be obtained [40, 41]. In our study, comparing the PRH of the lateral window techniques, the mean values were similar: 4.5 mm for a staged versus 4.2 mm for a simultaneous approach. Therefore the decision for a staged or simultaneous approach was not dependent on the 4 mm PRH. Therefore we assume that the experience of the supervising surgeon was the main factor for this decision. This had no negative influence on the implant survival rate (100% for the loaded implants).

In 2007 in a systematic review Aghaloo and co-workers [42] had already concluded that maxillary sinus augmentation procedures are well-documented. The long-term (>5 years) clinical success/survival of implants placed using this procedure, regardless of the graft material(s) used, was found to be similar to that of implants placed without a grafting procedure. Another study confirmed a lack of apparent differences in the survival rate of implants placed via different surgical approaches, which was 97.1% for both the lateral and transcrestal SFE techniques [43]. The results of the present study are thus consistent with recent investigations that reported survival rates of 99-100% for both techniques, with stable graft height around the implants [44-47]. Other studies have reported lower survival rates for either the lateral window technique (86%) [48] or the transcrestal technique (90.7%) [49].

In 2001 Tawil [31] suggested for a PRH of less than 5 mm when applying the simultaneous approach a healing period of more than 9 months to ensure high implant survival rates. We chose a healing period of 6 months also in cases with a PRH less than 5 mm (52%) without any negative influence on the long-term implant survival rate. Further research is needed to investigate the influence of PRH and healing periods on long-term implant survival rates.

In the present study we used graft material for all the SFE procedures. Only xenograft material was applied and no autologous bone was harvested. The goal was to reduce patient's morbidity and to improve the radiographic visibility of the SFE procedures. As an earlier study showed, the use of Bio-Oss® simplifies the creation of an adequate space in the sinus and helps to identify and analyze the grafted area [37]. As the visibility of the elevated site is better in the radiographs, the dentist has better control. Xenograft material is often preferred over more complex grafting procedures such as autologous bone grafting from the retromolar region, the chin or the iliac crest [50-52], and its use may prevent the type of unpredictable resorption observed with autologous bone grafting. The development of sinusitis or loss of the graft material is rare and does not seem to depend on the type of material used [53]. In our study all grafts were radiographically stable, no complication occurred regarding the graft material during or after surgery.

In the literature its discussed whether graft material is needed for SFE procedures. Some investigators avoided the use of any graft material [54, 55] without negative consequences. A systematic review showed that when the transcrestal SFE technique was performed without the use of a grafting material, only a moderate gain of new bone was detected, whereas SFE in conjunction with bone grafting resulted in a mean bone gain of 4.1 mm [10]. In the literature, the gain of bone height reported is between 5 and 8 mm for the lateral technique [40] and between 4 and 6 mm for the transcrestal technique [17, 37]. The data of the present study is similar to these earlier results.

Little information is available regarding the type of prostheses that are supported by implants placed by means of SFE procedures. The data of the present study shows that implants placed by means of SFE procedures were used to support different types of removable and fixed prostheses comprising a broad spectrum of restorations types.

The assumption that the transcrestal technique was used more frequently for single crowns on implants could not be confirmed in this study. The implants placed with the transcrestal technique were also used in bigger and more complex restorations such as full arch bridges or bars. We found a weak correlation between single crowns and the transcrestal technique.

Data were collected from a patient group that was highly compliant in terms of participation in the maintenance care program and the 5-year recall. The 5-year follow-up time used here is relatively long-intervall compared to other studies, which typically only have follow up times of 12 months [14] or up to 36 months [48].

The available radiographs were two-dimensional, similar to most of the other reported studies. The PRH was measured along the midline of the implant axis, which represents a minor limitation in the accuracy of the measurements. as it does not take into account all of the individual three-dimensional anatomical details. Because the floor of the sinus is not horizontally flat, the PRH may be different if measured at both approximal (mesially and distally of the implant) sites.

The measurements performed for the present study opens the discussion of the use of short implants in the posterior maxilla. In our study, the minimum standard implant length was 10 mm. Controversy exists over the standard implant length, and there is some inconsistency regarding the term "short implant," which may refer to a length of 6 mm or 8 mm. Among manufacturers a standard implant length is proposed to be more than 10 mm. One recent study has described short implants as being shorter than 9 mm another as being shorter than 5.5 mm. Both studies have reported acceptable implant survival rates [56, 57]. One study reported more complications for standard implants placed in combination with sinus grafting than for short implants placed without SFE in the posterior maxilla [58]. When the survival rates of various short implants were compared, the shortest implants (5.5 mm to 7 mm) were found to have a lower survival rate than the longer implants (8 mm or 8.5 mm), particularly in the maxilla compared to the mandible [59]. Factors other than PRH, including implant surface characteristics, patient behavior and loading conditions, may all impact the implant survival rate. Use of 8-mm implants in the patient group of this study could have reduced the number of required surgical SFE interventions by approximately 20%. However, we cannot predict whether the same implant survival rate could have been achieved.

The discussion regarding short implants and SFE procedures will continue. Increasingly, modern imaging techniques are used to produce three-dimensional views of the implants and the surrounding sinus anatomy. The detailed information obtained from these imaging modalities may aid in future decisions regarding whether SFE procedures are necessary or not.

Conclusion

We conclude that all SFE procedures are predictable and provide a good implant survival rate. The presurgical ridge height influences the choice of the SFE procedure: The PRH above implants placed using the lateral window technique was significantly smaller compared to the transcrestal technique. The choice of a simultaneous instead of a staged lateral window technique is also related to the expected primary stability of the implant, as judged by the surgeon's experience.

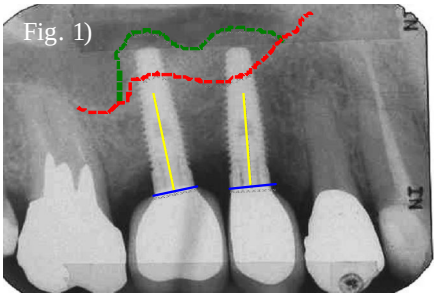
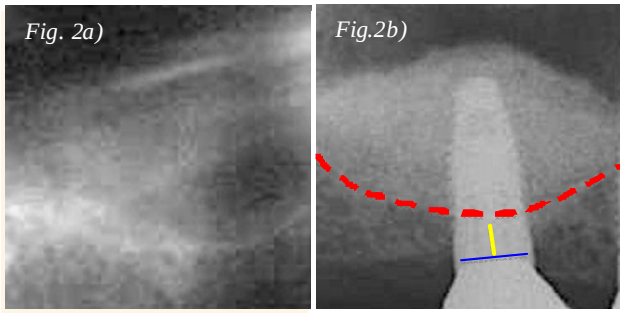


Figure 1): transcrestal technique

A 5-year follow-up radiograph: The original sinus floor was identified (red line) and the original ridge was traced (blue line). The known implant length was used to calibrate the measurement of the PRH (yellow line).

Graft material: slightly visible (green line).



Figures 2a & 2b: lateral window technique, staged approach

Radiographs of the same surgical site before a), and after b), a staged lateral SFE approach. The PRH is marked yellow.

Graft material: strongly visible.

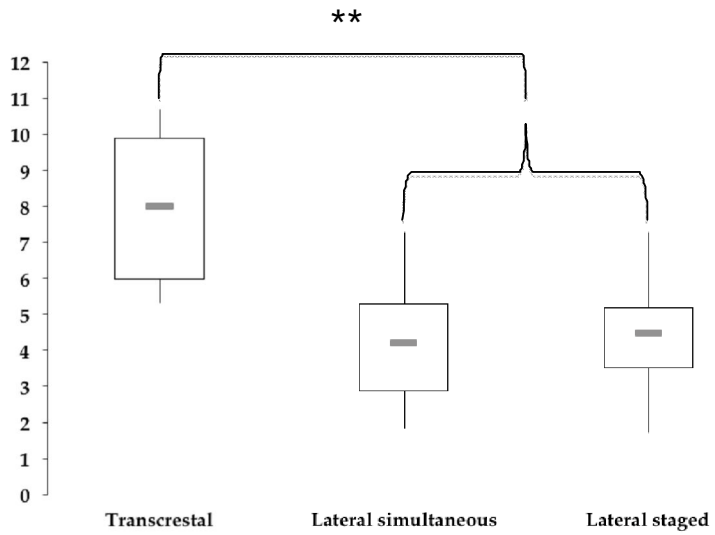


Figure 4: Presurgical ridge height in mm of the different SFE procedures (** = $p < 0.05$), the grey line indicates the mean value.

TABLES

Prosthesis	Type	Total Implants	Transcrestal SFE	Lateral SFE (simultaneous)	Lateral SFE (staged)
Fixed	Single crown	16	8	3	5
	Short bridge	18	3	5	10
	Full arch, fix	14	6	4	4
Removable	RPD / OD	35	15	9	11
	All	83	32	21	30

Table 1: SFE procedures applied and prosthetic restorations.

Surgical approach / technique	Edentulous			Dentate			Total		
	Implants N (%)	Patients N (%)	Impl. per patient	Implants N (%)	Patients N (%)	Impl. per patient	Implants N (%)	Patients N (%)	Impl. per patient
Transcrestal	15 (45,5%)	11 (68,8%)	1,4	16 (32,0%)	14 (38,9%)	1,1	31 (37,3%)	25 (48,1%)	1,2
Lateral simultaneous	9 (27,3%)	3 (18,8%)	3,0	12 (24,0%)	8 (22,2%)	1,5	21 (25,3%)	11 (21,2%)	1,9
Lateral staged	9 (27,3%)	2 (12,5%)	4,5	22 (44,0%)	14 (38,9%)	1,6	31 (37,3%)	16 (30,8%)	1,9
Total	33 (100%)	16 (100%)	2,1	50 (100%)	36 (100%)	1,4	83 (100%)	52 (100%)	1,6

Table 2: Implants and patients with respect to the SFE procedures.

Surgical approach / technique		Presurgical Ridge heigth PRH (mm)		
		Edentulous	Dentate	Total
Transcrestal	Mean	8,6	7,4	8,0
	Median	9,9	7,2	8,0
	SD	3,1	2,2	2,7
Lateral	Mean	3,5	4,8	4,2
simultaneous	Median	3,5	4,6	4,0
	SD	2,5	2,7	2,6
Lateral	Mean	4,3	4,5	4,5
staged	Median	4,9	3,6	4,4
	SD	2,1	3,1	2,8
Total	Mean	6,0	5,5	5,7
	Median	5,6	5,8	5,7
	SD	3,6	3,0	3,2

Table 3: The PRH in edentulous and partially dentate patients in relation to the SFE procedure.

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