Research article

Long-term stability of osseointegrated implants in bone regenerated with a collagen membrane in combination with a deproteinized bovine bone graft: 5-year follow-up of 20 implants

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Abstract

Background and objectives. The use of preimplant bone graft is often needed for an adequate implant placement. This clinical study evaluated the 5-year stability of 20 implants placed in bone that had been previously regenerated with a deproteinized bovine bone graft and a collagen membrane.

Materials and Methods. Clinical and radiological data were collected one and 5 years after implant placement.

Results. All implants remained stable throughout the study period with a mean Periotest value of -2.65. X-ray examination showed stable bone crest levels without angular defects and a mean bone loss between the 1st and the 5th year examination of 0.287 mm.

Discussion and Conclusion. The 20 implants were successfully integrated and were maintained in function over a 5-year follow-up period. Based on the clinical and radiological favourable results, we conclude that regenerated bone, formed under a collagen barrier membrane combined with a deproteinized bovine bone graft, responds like pristine bone to implant placement.

Keywords. Biomaterials, bone regeneration, bone grafting, dental implants.

1. Introduction

The use of osseointegrated implants to replace missing teeth is a recommended treatment modality for partially **[1]** and completely edentulous patients **[2]**. As the long-term prognosis of dental implants is adversely affected by inadequate bone volume, successful implant therapy requires adequate bone volume at the potential implant sites. In cases of deficient alveolar ridges, several surgical alternatives are used to increase the alveolar bone volume for implant placement **[3,4]**. One surgical technique uses barrier membranes for guided bone regeneration (GBR), which allows localized jawbone defects to be filled with new bone **[5]**. A well documented GBR surgical procedure is the lateral ridge augmentation technique with a second stage surgical approach in which implants are placed in the newly augmented bone ridge.

Clinical studies showed that autogenous bone graft in combination with a non-resorbable expanded polytetrafluoroethylene (e-PTFE) membrane, is a potential treatment for horizontal ridge augmentation before implant placement **[6,7]**. Frequent complications associated with non-resorbable membranes are soft tissue dehiscences during the healing period **[8,9]** and membrane bacterial contamination **[8]**. In addition, membrane removal during implant placement requires an extensive surgical exposure of the newly formed bone **[10]**.

One major disadvantage of the use of autogenous bone graft is the morbidity associated with the harvesting procedure **[11]**. Due to these disadvantages, the use of a resorbable membrane (causing fewer flap dehiscences) and in combination with bone substitutes (to avoid the morbidity associated with harvesting autogenous grafts) seems to be an effective surgical alternative for lateral ridge augmentation before implant placement **[10,12,13]**.

The aim of this study was to evaluate the 5-year long-term stability of 20 implants placed in a previously augmented ridge, using a collagen membrane in combination with a deproteinized bovine bone graft.

2. Materials and Methods

Twenty non-submerged ITI implants (Straumann AG, Basel, Switzerland)**[14]** were inserted in recipient sites of 10 partially edentulous patients (5 women and 5 men). Four to ten months prior to implant placement, a successful horizontal ridge augmentation was made with a deproteinized bovine bone graft (Bio-Oss, Geistlich AG, Wolhusen, Switzerland) covered by a collagenous membrane (Bio-Gide, Geistlich AG, Wolhusen, Switzerland). Patient, implant-site and implant characteristics are listed in **Table 1**.

Patient number	Gender	Age	Implant site	Implant type	Implant length
1	F	34.8	22	4.1 mm Ø	12 mm
2	H	44.4	21	4.1 mm Ø	12 mm
3	F	25.9	21	3.3 mm Ø	12 mm
4	F	67.3	13	4.1 mm Ø	12 mm
5	F	46.7	24	4.1 mm Ø	12 mm
			25	4.1 mm Ø	12 mm
			26	4.1 mm Ø	12 mm
6	H	60.1	25	4.1 mm Ø	12 mm
			26	4.1 mm Ø	12 mm
			27	4.1 mm Ø	12 mm
7	H	46.2	11	4.1 mm Ø	12 mm
8	F	56.1	25	4.1 mm Ø	12 mm
			26	4.1 mm Ø	12 mm
			15	4.1 mm Ø	12 mm
			16	4.1 mm Ø	12 mm
9	H	31.2	15	4.1 mm Ø	12 mm
			16	4.8 mm Ø	10 mm
			25	4.1 mm Ø	12 mm
			27	4.1 mm Ø	12 mm
10	H	70.1	21	3.3 mm Ø	12 mm

Table 1. Characteristics of patients and implants placed following ridge augmentation using the staged GBR procedure.

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After completion of implant restoration, the patients were monitored in a maintenance program. Over a 5-year period, they were examined annually using the same protocol as for prospective long-term studies of non-submerged ITI implants in pristine bone **[15]**. The following clinical and radiological parameters were evaluated for each implant:

- Suppuration in the peri-implant sulcus (0 = no suppuration, 1 = suppuration).
- Modified plaque index (mPLI) assessed at four aspects around the implants **[16]**. For each implant, one mPLI value was calculated based on the mean of the four obtained values.
- Modified sulcus bleeding index (mSBI) assessed at four aspects around the implants **[16]**. For each implant, one mSBI value was calculated based on the mean of the four obtained values.
- Probing depth (PD) measured at four aspects around the implants. For each implant, one PD value was calculated based on the mean of the four obtained values.
- The distance from the implant shoulder to the mucosal margin (DIM), measured at four aspects around the implants with the same periodontal probe (Hu-Friedy PGF-GFS, Hu-Friedy, Chicago, IL,USA).
- Clinical attachment level (AL) assessed at four aspects around the implants and calculated for each site by adding probing depth and recession depth (AL = PD + DIM).
- Height of keratinized mucosa (KM): the distance between the marginal soft tissue and the mucogingival junction, measured in mm on the vestibular site of each implant with the same periodontal probe.
- Periotest value: the Periotest (Siemens, Bensheim, Germany) method was utilized as previously described **[17]**.
- The distance between the implant shoulder and the first visible bone-implant contact (DIB) was measured at the mesial and distal aspects of each implant, using standardized periapical radiographs with the long-cone paralleling technique and the Rinn System holding device (XCP Instruments, Rinn Corporation, Elgin IL, United States). To evaluate radiological assessment of crestal bone loss around the implants computerized images were used aided by a software system (Digora for Windows, version 2.1 rev. 2, Soredex, Helsinki, Finland). For each implant, one DIB value was evaluated by calculating the average of the mesial and distal values. The 5-year DIB values were compared with the 1-year DIB values to evaluate the crestal bone changes around the implants over the 4-year period between both examinations (DIB5y – 1y).

Based on clinical and radiological findings, each implant was classified as either successful or non successful, using the success criteria followed in previous prospective studies of implants in non-regenerated bone **[15]**:

1. Absence of persistent subjective complaints such as pain, foreign body sensation, and/or dysaesthesia
2. Absence of peri-implant infection with suppuration
3. Absence of implant mobility
4. Absence of continuous radiolucency around the implant

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Statistical analysis of the study results was conducted using the statistical program SPSS 15 (Statistical Package for Social Sciences, SPSS Inc., Chicago). To determine if the quantitative variables followed a normal distribution, the Shapiro-Wilk test was applied. The variables that followed a normal distribution were expressed with the mean ± standard deviation (mean ± SD), while the variables that were not normally distributed were expressed with the median and the aptitude. The comparison of clinical parameters PPD, DIM, AL, KM, Periotest value and DIB between the first (1st year) and the second (5th year) examination was carried out with the t test for paired data with a normal distribution and the Wilcoxon Signed Rank test for variables that were not normally distributed. The significance level chosen in all statistical tests was 95% ($p<0.05$).

3. Results

During the 5-year observation period, none of the 10 patients complained of pain, foreign body sensation or dysaesthesia at implant sites. The peri-implant soft tissues were healthy without signs of infection or suppuration. The clinical parameters at the 1- and 5-year examinations are summarized in **Tables 2 and 3** respectively.

Implant Number	Loc.	Supp.	mPLI	mSBI	PD	DIM	AL	KM	Perio
1	22	0	0	0	2	0	2	5	-5
2	21	0	0	0	2	0	2	5	-7
3	21	0	0	0	2	0	2	5	-5
4	13	0	0	0.5	2	0	2	5	-5
5	24	0	0	0	2	0	2	3	-7
6	25	0	0	0	2.25	0	2.25	3	-8
7	26	0	0	0	2	0	2	3	-6
8	25	0	0	0	3	0	3	3	-2
9	26	0	0	0	3	0	3	3	-3
10	27	0	0	0	3	0	3	3	-3
11	11	0	0	0	2.25	0	2.25	5	2
12	25	0	0	0	2.25	0	2.25	1	-2
13	26	0	0	0	3	0.25	3	1	-2
14	15	0	0	0	2	0	2	3	-1
15	16	0	0	0	2	0	2	3.5	--1
16	15	0	0	0	2.5	0	2.5	5	-5
17	16	0	0	0	2.5	0	2.5	3	-4
18	25	0	0	0	2	0	2	2	-5
19	27	0	0	0	3	0	3	2	-5
20	21	0	0	0	2.75	0	2.75	3	-6
Mean/Median		0	0	0.025	2.25	0.01	2.25	3.55	-3.9
SD		0	0	0	0.42	0.05	0.42	1.14	2.63

Table 2. Clinical parameters at the 1-year examination.
Implant number: consecutive number of implant; Loc.: location of implant according to WHO-classification; Supp: Suppuration; mPLI: modified plaque index; mSBI: modified sulcus bleeding index; PD: probing depth; DIM: distance implant shoulder to the mucosal margin; AL: clinical attachement level; KM: keratinized mucosa; Perio: PerioTest value.

The mean value for the mPLI and mSBI were below 0.5 and did not show any significant differences between the initial and the final examination. The median PD at the 1-year examination was 2.25 mm and 2.5 at the 5-year examination respectively and their difference was statistically significant (p=0.031). DIM values were stable and recorded between 0 mm and 1.5 mm at the 5-year examination. The difference between the 1-year and 5-year median DIM values was not statistically significant (p=0.25). The measurements of DIM values allowed the calculation of the clinical attachment level (AL=PD+DIM). The AL values ranged from 2 mm to 4 mm, resulting in a median value of 2.75 mm at the 5-year examination versus 2.25 mm at the 1-year examination. Their difference was statistically significant (p=0.01). All implants showed ankylotic stability during the 5-year observation period. The median KM value ranged from 3.55 mm at the 1-year examination to 3.05 mm at the 5-year examination. Their difference was statistically significant (p=0.026). The evaluated Periotest values varied from -8 to 3 with a mean value of -3.9 at the 1-year examination and from -7 to 4 with a mean value of -2.65 at the 5-year examination. Their difference was statistically significant (p=0.021).

Implant Number	Loc.	Supp.	MPLI	mSBI	PD	DIM	AL	KM	Perio
1	22	0	0	0	3	0	3	3	-3
2	21	0	0	0	3	0	3	5	-7
3	21	0	0	0	2.25	0	2.25	5	4
4	13	0	0	1	2	1.5	3.5	2	-4
5	24	0	0	0	2.25	0	2.25	3	-5
6	25	0	0	0	2	0.25	2.25	3	-7
7	26	0	0	0	2	0.25	2.25	3	-6
8	25	0	0	0	3	0	3	3	0
9	26	0	0	0	3	0	3	3	-1
10	27	0	0	0	3	0	3	3	-3
11	11	0	0	0	3	0	3	5	6
12	25	0	0	0	2.5	0	2.5	2	-2
13	26	0	0	0	3	0	3	3	-2
14	15	0	0	0	2	0	2	3	1
15	16	0	0	0	2	0	2	3	-1
16	15	0	0	0	2.5	0	2.5	5	-5
17	16	0	0	0	2.5	0	2.5	3	-4
18	25	0	0	0	2	0	2	2	-6
19	27	0	0	0	3	0	3	2	-5
20	21	0	0	0	3	0	3	2	-3
Mean/Median		0	0	0.05	2.5	0.1	2.75	3.05	-2.65
SD		0	0	0	0.44	0.33	0.44	0.99	3.45

Table 3. Clinical parameters at the 5-year examination.
Implant number: consecutive number of implant; Loc.: location of implant according to WHO-classification; Supp: Suppuration; mPLI: modified plaque index; mSBI: modified sulcus bleeding index; PD: probing depth; DIM: distance implant shoulder to the mucosal margin; AL: clinical attachement level; KM: keratinized mucosa; Perio: PerioTest value.

The 5-year periapical radiographs showed normal peri-implant bone structures for all implants, without a continuous peri-implant radiolucency **(Figure 1)**. All implants showed

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stable crestal bone levels and no sign of angular defects. Mean DIB values at the 1- and 5-year examinations were 2.592 mm and 2.897 mm respectively. Direct comparison of the 1st and 5th year examinations showed a mean bone loss of 0.287 mm between both examinations **(Table 4)**.

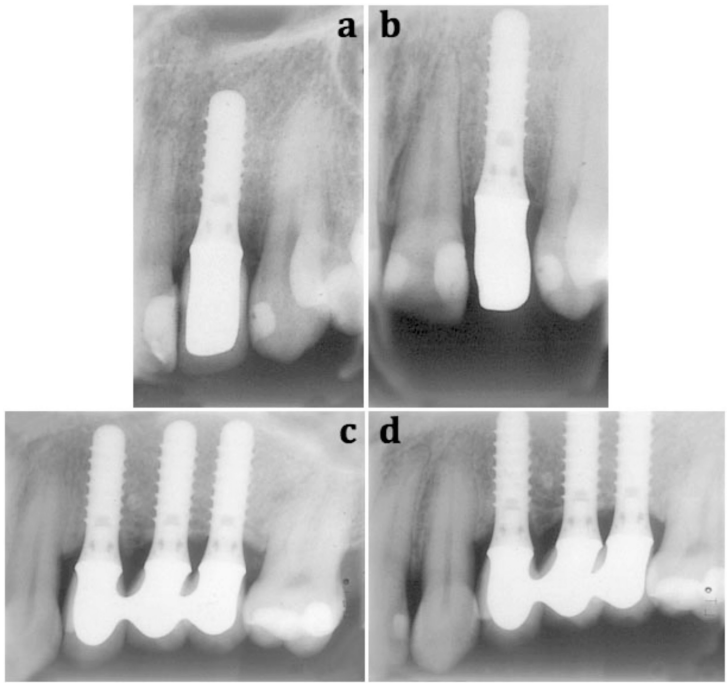

Figure 1. Radiological follow-up. Normal peri-implant bone structures around implants 1-year after implants placement (**a et c**). Stable crestal bone level with no signs of angular defect 5-year after implant placement (**b et d**).

Examination period	Minimum	Maximum	Mean (SD)
Year 1	1.52	4.885	2.592 (0.846)
Year 5	1.73	5.025	2.879 (0.863)
ΔDIB 5y-1y			0.287 (0.282)

Table 4. DIB values of 20 implants (DIB: distance from implant shoulder to first bone to implant contact).

4. Discussion

This clinical study presents clinical and radiological one and 5-year data of 20 implants. These were inserted in bone that had been previously augmented with a deproteinized bovine bone graft (Bio-Oss), combined with a collagen barrier membrane (Bio-Gide). The effectiveness of the combined collagen membrane and a deproteinized bovine bone graft, on horizontal ridge augmentation before implant placement, had been confirmed by other clinical studies **[7,10,13]**.

After the osseointegration of implants, a continuous clinical evaluation is necessary. This allows the detection of early signs of peri-implant disease. The clinical and radiological results obtained are comparable with those of various studies on non-submerged implants placed in pristine, non-regenerated bone **[15,18]**. The mean mPLI values were very low and

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the peri-implant soft tissues were in good health, without signs of infection or suppuration, indicating the patients' excellent oral hygiene. The mSBI values were also low as shown in this study.

The depths of peri-implant recession, five years after implants insertion, were stable and ranged between 0 to 1.5 mm. The median PD and AL values (2.25 and 2.75 respectively at the 5-year examination) were the same or slightly lower than those found in previous studies **[15,18]**. However, controversies exist on the extent to which these parameters are appropriate indicators for a possible pathology of the peri-implant structures **[19]**, since the difference between the used periodontal probes and the exerted pressure certainly influence the results of probing around the implants. Care should be taken when making direct comparisons of PD and clinical AL between different studies as differences when exerting pressure and between various periodontal probes may impact results differently when the implants are examined.

Keratinized mucosa was present on the vestibular site of all implants, as a result of soft tissue manipulation during implant surgery **[13]**. During the 20 implant placements in this study, the initial incision line was moved slightly to the palatal side of the ridge to preserve as much keratinized mucosa as possible on the vestibular side of the future implant restoration **[20]**.

All implants revealed a firm anchorage in the jaw bone during the study period, without presence of mobility, confirmed by the values of Periotest. The mean Periotest value was -2.65 five years after implants insertion and was proportional to the mean Periotest values of previously published studies **[19]**. However, its value as a reliable parameter for implant outcome is unclear. As Periotest values also depend on the implant type, its length, its width, bone quality and length of follow-up time **[17]**, further studies are needed to determine whether changes in Periotest values reveal initial alterations to the original bone to implant interface before other clinical parameters **[16]**. The Periotest values in this study confirmed the absence of implants mobility and their survival through the 5-year follow-up period.

The distance between the implant shoulder and the first visible bone to implant contact was measured on the mesial and distal side of each implant, utilizing standardized periapical radiographs. The mesial and distal radiological bone level of each implant reflects the vestibular and lingual bone levels. The 5-year x-ray examination showed stable crestal bone levels, without the presence of angular defects, with a mean bone loss of 0.287 mm between the two examinations. The mean DIB value of 2.879 mm at the 5-year examination was similar to published radiological data on non-submerged implants in non-regenerated bone **[7,18]**.

According to the clinical and radiological observations, all 20 implants were considered successfully integrated, with functional ankylosis and were effectively maintained in function over a 5-year follow-up period. They did not present persistent subjective complaints such as pain, foreign body sensation dysaesthesia, peri-implant tissue infection, mobility, and continuous radiolucency around the implants **[15]**. The survival and success rates in a 5-year observation period were 100%. These favourable results concurred with results from 5-year studies on ITI implants inserted in non-regenerated bone **[15,18]**. Based on these results we can conclude that regenerated bone, formed underneath collagen membranes, responds like pristine bone to implant placement.

The present study confirms the favourable results of other long-term studies on implants in regenerated bone using the GBR process. In the literature, different success rates

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were obtained depending on the technique and bone material used during the regeneration treatment, for example a GBR procedure with a synthetic hydroxyapatite (HA) spacer under a collagen membrane **[12]**, or various forms of bone regeneration with allograft or collagenated equine xenograft in combination with platelet-rich fibrin autogenous membranes **[3,4]**. The quantity of new bone biomaterials available nowadays on the market is considerable. Each combination of biomaterials and techniques must be evaluated very carefully in order to define the adequate clinical protocol for each combination.

5. Conclusion

Clinical and radiological results of the present study on 20 implants placed in regenerated bone showed that all implants were successfully integrated at the 5-year examination. They met the success criteria and functioned free of complications for patients. The analysis of clinical parameters concurred with the results of studies on implants inserted in non-regenerated bone as well as on implant placed simultaneously with some other GBR techniques. This therapeutic option seems therefore to have a very favourable prognosis. However, many biomaterials and techniques are nowadays available, and this study recalls us the need of adequate investigation and validation of each new therapeutic solution.

Disclosure of interests

The authors have no conflict of interest to report.

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