Successful Bone Formation at Immediate Transmucosal Implants: A Clinical Report

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The aim of this study was to test whether bone could be formed in peri-implant defects at immediate transmucosal implants using guided bone regeneration. Ten patients (median age 48 years) underwent comprehensive dental care including the placement of an implant into an extraction socket immediately following removal of a tooth. An expanded polytetrafluoroethylene membrane and the mucoperiosteal flap were adapted around the neck of the implants, leaving the sites to heal in a transmucosal fashion. During implantation (baseline) and at membrane removal surgery 5 months later, the following clinical measurements from the implant shoulder were assessed at six sites: implant-bone contact (defect depth), level of the alveolar crest, level of the membrane, and distance from the crest to the implant body (defect width). Estimates of the defect volume bordered by the membrane, the implant, and the bony walls were calculated. At baseline, the mean defect depth was 4.7 mm (SD 1.3 mm, range 1 to 14 mm). At membrane removal, the mean defect depth had decreased to 2.1 mm (SD 0.8 mm). Compared to baseline, this decrease was statistically significant ($P < .01$). The mean increase in bone height at the deepest defect site of each implant was 6.7 mm (SD 3.0 mm), which was significant ($P < .01$). At baseline, the mean value for the defect volume estimates was 9.45 mm^3 (SD 5.75 mm^3). At membrane removal, a significant decrease ($P < .01$) was found. After 5 months, 94% of the area beneath the membrane was filled with new bone. It was concluded that guided tissue regeneration at immediate transmucosal implants is successful in generating bone into peri-implant defects.
(Int J Oral Maxillofac Implants 1998;13:522–530)

Key words: e-PTFE membrane, guided bone regeneration, implantation, new bone formation, transmucosal

Currently available dental implant systems that have a high documented rate of success are based exclusively on the principle of osseointegration.[1,2] The clinical procedures allowing this tissue integration to predictably occur depend on a sufficient amount of host bone at the recipient site.[3] Recently, it has been demonstrated that the method of guided bone regeneration (GBR) may also be used successfully to increase local bone volume in areas of insufficient jawbone volume for placement of endosseous implants. Results are generally more favorable in small than in large defects.

Following tooth loss, the bone of the alveolar process has been shown to undergo a continuous resorptive process that is most pronounced in the early phases after tooth removal.[4–6] To reduce the problems resulting from this loss of bone, dental implants have been placed into fresh extraction sockets.[7,8] When implants are placed into extraction sockets, a partial incongruency between the outer surface of the implant and the bony walls of the socket often results in a bone deficit in the peri-implant area. Instead of reducing the height of the alveolar ridge to obtain sufficient width for implantation,[9] barrier membranes may be applied to correct this deficit by permitting the peri-implant area to fill with new bone.[10–12] In these studies, surgeries were performed to submerge both the implant and the membrane under the soft tissue flap, thus aiming at healing by primary intention.

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Table 1 Gender, Age, Reason for Tooth Extraction, Region of Implantation, Implant Type and Length, Membrane Type, and Complications During the Regenerative Period for All Implants

Patient no.	Gender	Age (y)	Reason for tooth extraction	Region	Implant type*	Implant length (mm)	Membrane type**	Complication during regeneration
1	F	61	Fracture	15	HC	10	GTAM-4	
			Periodontitis	16	HC	10	GTAM-4	
2	F	57	Fracture	14	HC	10	GTAM-4	
3	F	48	Caries	12	HC	10	GTAM-6	
4	M	38	Fracture	11	HC	10	GTAM-4	
5	F	49	Fracture	44	HC	10	GTAM-4	Infection
6	M	47	Periodontitis	14	HS	8	GTAM-4	
7	M	47	Periodontitis	46	HS	10	GTAM-6	
8	F	25	Periapical lesion	24	HC	12	GTAM-4	
9	M	55	Fracture	22	HC	10	GTAM-4	
10	M	60	Fracture	22	HC	12	GTAM-4	Infection

*HC = hollow cylinder; HS = hollow screw.
**GTAM-4 = GTAM Oval-4; GTAM-6 = GTAM Oval-6.

The technique of GBR has previously been used in conjunction with the placement of transmucosal implants into fresh extraction sockets.[13–16] Case reports of this method were first presented in 1993.[13,17] The critical difference from the aforementioned procedures is that the implant was deliberately left in a transmucosal position during the entire phase of bone regeneration.[13,14] Consecutive case studies on the success rate and long-term clinical performance of immediate implants placed transmucosally with this method have been limited to a methodologic report describing 25 implants in 16 patients,[14] and a recent cross-sectional analysis comparing clinical results of immediate transmucosal implants and implants placed under standard conditions at 1 year following the placement of fixed prostheses.[16]

The aim of the present study was to test whether bone could be generated into peri-implant defects involving immediate transmucosal implants using GBR.

Materials and Methods

Ten patients in need of implant treatment were informed about the study and gave their consent to participate. The patients, five females and five males, had a median age of 48 years (range 25 to 61 years) and were in good general health. Comprehensive dental care, combined with the replacement of one or two teeth by an ITI dental implant (Straumann AG, Waldenburg, Switzerland), was rendered to all patients.

The primary reasons for these tooth extractions were root fractures and advanced stages of periodontitis (Table 1 and Figs 1a and 1b). The techniques for extraction, implantation, and guided tissue regeneration have recently been described.[14] In brief, after sulcular incisions, buccal and lingual/palatal mucoperiosteal flaps were raised in the area of the tooth to be extracted. During tooth removal, care was taken to minimize the trauma to the walls of the alveolar housing. A congruent implant bed was then prepared in the apical portion of the alveolus or beyond the former apex of the tooth to allow for a hollow-cylinder or hollow-screw implant to be seated (Fig 2). Eleven implants were thus placed in the 10 patients, and all exhibited primary stability (Fig 3).

Subsequently, an expanded polytetrafluoroethylene (e-PTFE) membrane (GTAM, oval-4 or oval-6, W. L. Gore & Associates, Flagstaff, AZ) was adapted around the neck of the implant extending 2 to 3 mm onto the bony walls of the defect (Fig 4). Close adaptation and stability of the membrane was achieved by punching and tightly fitting it around the neck of the implant. Likewise, the mucoperiosteal flap was tightly adapted around the neck of the implant. If necessary, releasing incisions were made through the periosteum of the flap to allow for good adaptation to the neck portion of the implant. In this way, healing with the implant in a transmucosal position was attempted (Fig 5). Gender, age, reason for tooth removal, region in the dentition, type and length of implant, type of e-PTFE membrane, and complications during the regenerative phase are all presented in Table 1.

Antibiotic coverage for the surgical procedure and the initial phase of healing by a regimen of 375 mg of penicillin three times per day for 7 days was prescribed. Patients were instructed to refrain from mechanical plaque removal in the area of implantation. Instead, plaque control was managed chemically by use of a 0.1% chlorhexidine solution in twice-daily

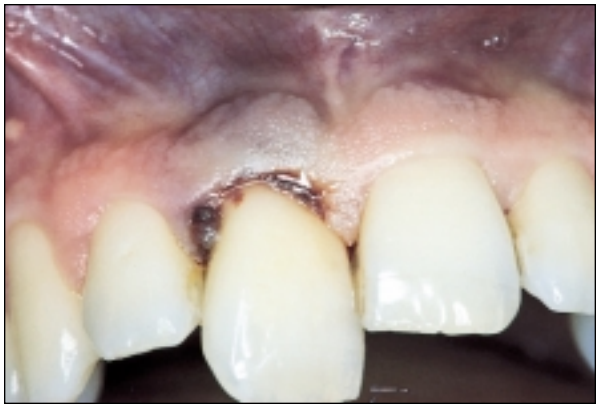


Fig 1a Right central incisor fractured as a result of a sports accident.

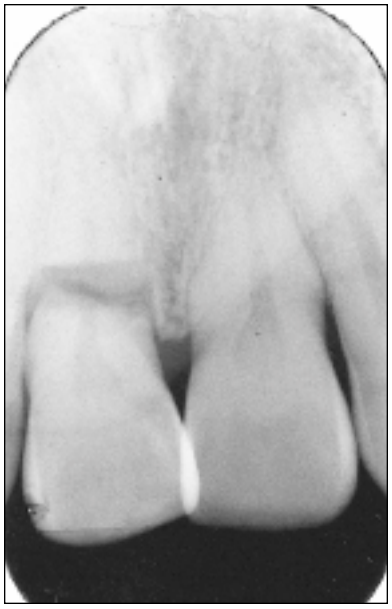


Fig 1b *(Right)* Radiograph of right and left maxillary incisors.

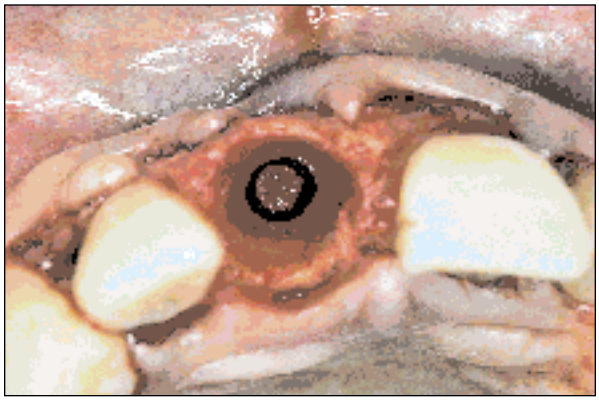


Fig 2 A congruent bed capable of hosting a hollow cylinder implant has been prepared beyond the apical termination of the alveolus.

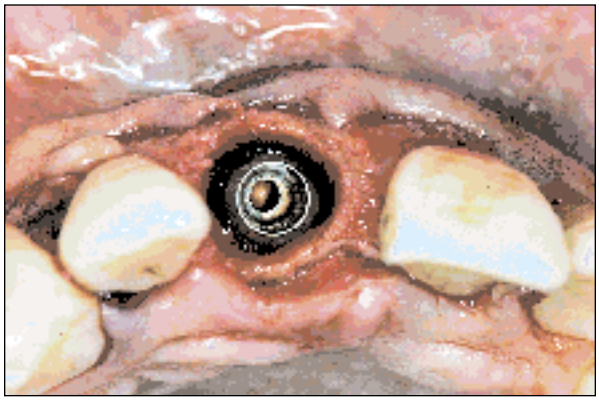


Fig 3 A hollow cylinder implant has been placed with primary stability in the prepared bony bed. Note the incongruency of the walls of the alveolar socket and the surface of the titanium implant in the more coronal portion.

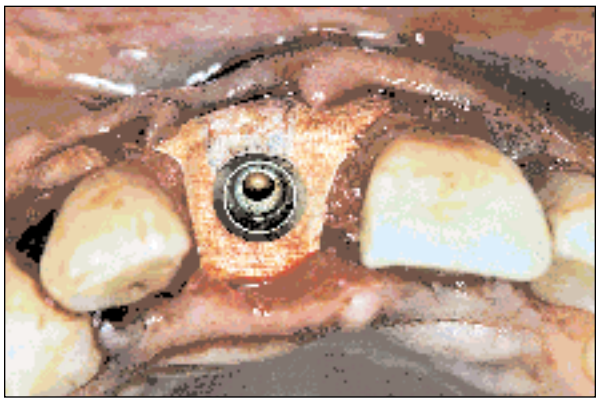


Fig 4 An e-PTFE membrane has been adapted around the neck of the implant, thus covering the bone defect and extending 2 to 3 mm onto the intact bony walls. The membrane has been stabilized by fitting it tightly around the neck of the implant.

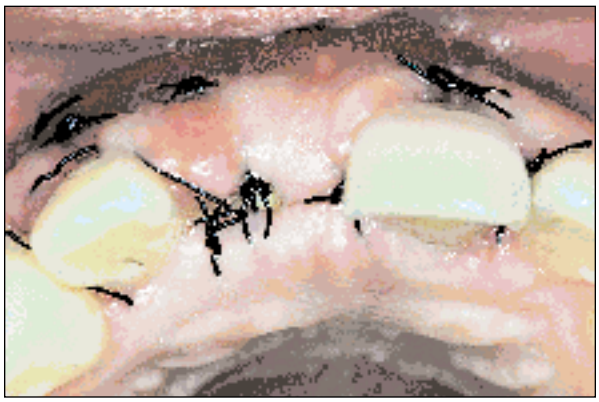
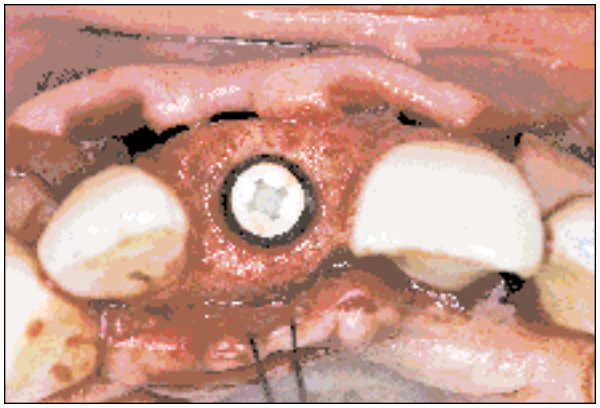
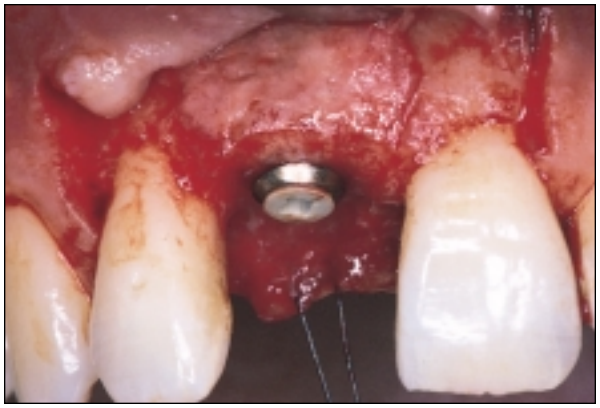


Fig 5 The clinical situation at suture removal 1 week following implantation. The mucoperiosteal flap is still tightly adapted around the implant. The transmucosal position of the implant was maintained throughout the regeneration period.





Figs 6a and 6b Occlusal *(left)* and buccal *(right)* views of the regenerated area after membrane removal. Note excellent bone regeneration in the previous peri-implant defect space in intimate contact with the implant surface.

rinses for 3 weeks, as well as a gel, also containing 0.1% chlorhexidine, in twice-daily topical applications during the entire regeneration period. Sutures were removed 7 to 10 days following implantation. Recall visits were scheduled weekly for the first 6 weeks and monthly thereafter.

Five months following implantation, reentry surgeries were carried out for removal of the nonresorbable barrier membranes (Figs 6a and 6b). Buccal and oral flaps were again raised, and the membranes were exposed. After dissection of the membrane, the quality and level of the tissues surrounding the implant were examined. Subsequently, the flaps were adapted around the neck of the implant and sutured. One week later, the sutures were removed, and prosthetic therapy was conducted (Fig 7).

During implantation (baseline) and at membrane removal surgery 5 months later (reentry), clinical photographs were taken for documentation, and the following clinical measurements were obtained from the implant shoulder at six sites (mesiobuccal, buccal, distobuccal, distolingual, lingual, mesiolingual): implant-bone contact (defect depth), level of the alveolar crest, level of the membrane, and distance from the bone crest perpendicularly to the implant body (defect width). Estimates of the defect volume bordered by the membrane and the bony walls were calculated. The defect volumes were determined by multiplying defect depth × defect width × circumference of the implant using the vertical and horizontal measurements at the six sites around each implant. All data were analyzed by descriptive methods (QQ-plots, box-plots) and by calculating mean values and standard deviations (SAS, Cary, NC). Student's paired *t* test was applied to detect differences over time. The level of significance in all tests was set at $\alpha = .01$.

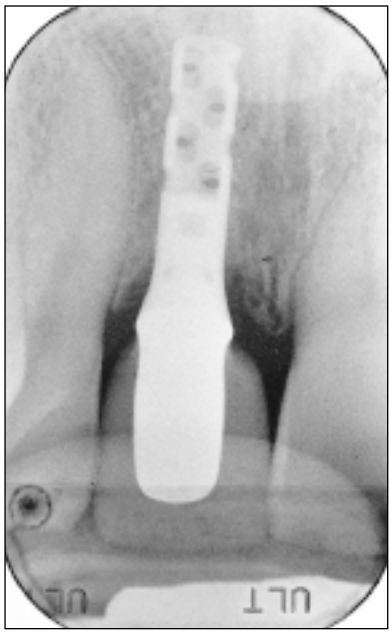


Fig 7 Radiograph of implant and crown replacing the lost maxillary right central incisor.

Results

All implants remained stable throughout the study period. All implants could be used as abutments for single crowns or fixed prostheses. The overall success rate for implant integration was, therefore, 100%.

At baseline, the mean defect depth of all sites measured was 4.7 mm (SD 1.3 mm, range 1 to 14 mm), while the mean defect width was 1.4 mm (SD 0.5 mm, range 0 to 3 mm) (Table 2). The mean

defect depth for each patient ranged from 3.5 to 7.3 mm, and the mean defect width for each patient ranged from 0.8 to 2.5 mm. The deepest sites in each patient ranged from 5 to 14 mm.

Table 2 Baseline Defect Depth and Width for All Sites in All Patients

	Defect depth (mm)		Defect width (mm)	
Patient no.	Mean	Range	Mean	Range
1	3.7	1–10	0.8	0–3
2	3.8	1–8	1.2	0–3
3	3.5	1–6	0.9	0–2
4	4.8	3–8	1.1	1–2
5	4.7	3–7	1.3	0–2
6	3.8	2–5	1.4	0–3
7	4.0	2–5	1.0	0–2
8	7.3	3–14	1.8	1–3
9	4.3	2–9	2.5	2–3
10	6.8	4–12	1.7	0–3
Mean*	4.7		1.4	
SD	1.3		0.5	

*Mean of all patients.

Table 3 Mean Values (± SD) for Baseline Defect Depth at Six Sites

	Defect depth (mm)	
Site	Mean	SD
Distal	2.7	1.4
Distobuccal	5.8	3.6
Distolingual	4.5	2.2
Mesial	2.7	1.8
Mesiobuccal	7.0	2.5
Mesiolingual	4.3	2.5

Table 4 Distribution (%) of Sites at Baseline and at Membrane Removal According to Depth (0–3 mm), (4–6 mm), (> 6 mm)

	Sites		
Depth (mm)	All	Deepest	Shallowest
Baseline			
0–3	45%		90%
4–6	30%	30%	10%
> 6	24%	70%	
Reentry			
0–3	89%	80%	100%
4–6	11%	20%	

The mean values for the bone-implant contact were greatest at the buccal aspects (mean 6.4 mm), somewhat smaller at the lingual (mean 4.4 mm) and smallest at the mesial and distal aspects (mean 2.7 mm) (Table 3).

At baseline, 45% of all sites ranged from 0 to 3 mm for defect depth, 31% ranged from 4 to 6 mm, and 24% were deeper than 6 mm (Table 4). Seventy percent of the deepest sites in each patient were 6 mm or more, and 30% were between 4 and 6 mm. Only 10% of the most shallow sites were 4 to 6 mm deep, while the remaining 90% measured 3 mm or less in depth.

Before flap closure after implant placement at GBR surgery, the mean level of the membrane measured from the shoulder of the implant was 1.5 mm (SD 0.8 mm) and ranged from 0.3 to 2.7 mm in the 10 patients. At the reentry operation, the membrane was located somewhat more apically at a mean distance of 2.0 mm from the shoulder (SD 0.7 mm).

In two patients, marginal inflammation and signs of infection had developed around the implants during the healing period. Consequently, the membranes had to be removed prematurely at 4 months following placement. In the remaining eight patients, the membranes were removed after a mean period of 5 months after implantation.

At the time of membrane removal, the mean defect depth for all sites was 2.1 mm (SD 0.8 mm, range 0 to 4 mm), while the mean width of the defect at the bony crest was 1.3 mm (SD 0.7 mm, range 0 to 3 mm) (Table 5). The mean defect depth for each patient ranged from 0.5 to 3.2 mm. The deepest sites in each patient ranged from 1 to 4 mm.

Table 5 Reentry Defect Depth and Crestal Defect Width for All Sites in All Patients

	Defect depth (mm)		Crestal defect width (mm)	
Patient no.	Mean	Range	Mean	Range
1	1.9	0–3	0.0	0
2	0.5	0–1	1.0	1–1
3	1.5	1–2	0.9	0–2
4	3.2	2–4	1.7	1–2
5	3.0	3–4	1.2	1–2
6	1.8	1–2	2.3	1–3
7	2.0	1–3	2.2	1–3
8	1.8	1–3	1.2	1–2
9	2.5	0–4	0.5	0–1
10	2.5	2–3	1.7	0–3
Mean*	2.1		1.3	
SD	0.8		0.7	

*Mean of all patients.

At this time point, 89% of all sites have a defect depth ranging from 0 to 3 mm, and 11% have a defect depth of 4 to 6 mm (Table 4). Eighty percent of the deepest sites in each patient are 0 to 3 mm deep, and 20% are between 4 and 6 mm. All (100%) of the most shallow sites measure 3 mm or less.

The mean increase in bone height as measured from the membrane to the first bone-implant contact was 2.7 mm (SD 1.3 mm, range 1.7 to 5.5) (Table 6). This increase was statistically significant ($P < .01$). The mean increase in bone height at the deepest defect site in each patient was 6.7 mm (SD 3.0 mm, range 4 to 14 mm) and was also highly significant ($P < .01$). All sites that were originally 3 mm deep or more gained an average of 4.4 mm (SD 2.2 mm) of bone height, which also represented a statistically significant difference ($P < .01$).

At baseline, the mean value for the defect volume estimates was 9.45 mm^3 (SD 5.75 mm^3, range 3.0 to 21.0 mm^3) (Table 7). At membrane removal, a highly significant change ($P < .01$) in the defect volume estimates was encountered (mean change 9.10 mm^3, SD 5.82 mm^3, range 1.5 to 21.0 mm^3). Overall, 94% (range 50 to 110%) of the area beneath the membrane was filled with new bone (Fig 8). The two implants that had exhibited signs of infection during the regeneration period showed only 78% and 50% of bone fill.

Table 6 Mean Linear Change in Bone Height for Each Patient from Baseline to Reentry Beneath the Membrane at All Sites, at the Sites Exhibiting More Than 3 mm of Bone Deficit at Baseline, and at the Deepest Site at Baseline in Each Patient

	Mean linear change (mm)		
Patient no.	All sites	Sites ≥ 3 mm	Deepest site
1	2.0	5.3	8
2	3.3	5.5	7
3	2.3	3.4	5
4	1.7	2.3	8
5	1.7	4.0	5
6	2.1	2.0	4
7	1.9	3.0	4
8	5.5	9.7	14
9	1.8	5.0	5
10	4.3	4.0	7
Mean*	2.7	4.4	6.7
SD	1.3	2.2	3.0

*Mean of all patients.

Table 7 Volume Estimates for Each Patient at Baseline and Amount of Decrease Between Baseline and Reentry

Patient no.	Baseline volume estimate (mm^3)	Decrease in volume estimate (mm^3)
1	13.5	13.5
2	10.5	11.5
3	3.8	3.8
4	8.0	8.0
5	5.0	4.8
6	3.0	1.5
7	4.2	4.5
8	21.0	21.0
9	12.0	12.0
10	13.5	10.5
Mean*	9.45	9.10
SD	5.75	5.82

*Mean of all patients.

Discussion

The results of the present study demonstrate that the clinical method of GBR may be used successfully to generate bone into defects around transmucosal implants placed into fresh extraction sockets. In this

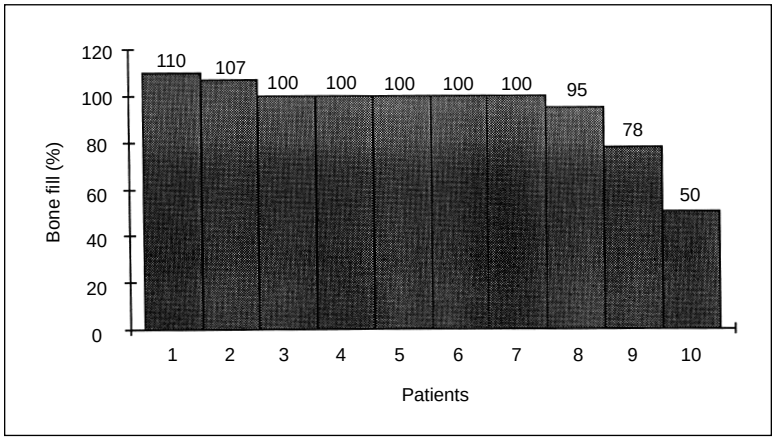


Fig 8 Percentage of bone fill within the space delimited by the membrane, the bony walls of the alveolus, and the implant surface. Measurement errors leading to values of bone regeneration greater than 100% were partly caused by displacement of the membranes between placement and removal.

context, it is important to realize that both the membranes and the soft tissue flaps were adapted around the neck of the implants, thus leaving the latter in a transmucosal position.

Previous investigators had claimed that primary wound closure following GBR surgery was a prerequisite for the formation of mineralized bone.[11,18] This statement was based on the finding that bone formation was less favorable when dehiscences occurred than in situations where the soft tissues remained intact during the entire regenerative period.[11,19,20] As a consequence of those results, it may be concluded that a flap dehiscence following primary wound closure represents a complication usually leading to a compromised healing outcome. Based on the results of the present study, implants placed in a transmucosal position per se did not impair the successful outcome of the bone regeneration process. However, it was recognized that in the presence of flap dehiscence, inflammation, and infection, as noted in two patients in the present study (no. 5 and no. 10), defect fill with new bone was not as great as bone fill, when a flap dehiscence did not occur. Hence, infection control appears to be the key factor for an optimal treatment outcome, rather than merely the choice of submerged or transmucosal implant position.

In the present study, exposure of the membrane and subsequent infection was noted in 2 of 11 implants. Exposure and infection seem to be common findings associated with bone regeneration at immediate implants.[11,19–21] Conflicting results have been reported regarding the amount of bone regeneration that occurs in the presence of exposure. Some investigators have reported compromised results,[19,22] while others still obtained very good defect fill with new bone.[12] Although only two occurrences are reported, the present material demonstrated impaired results associated with membrane exposure for transmucosal implants. In a retrospective study of bone regeneration to augment edentulous ridges or to fill nonspacemaking defects, infection was also the only serious complication jeopardizing the outcome of 21 sites in a situation with submerged membranes.[23]

Documented attempts to fill defects with bone around freshly placed submerged implants have consistently led to osseointegration of the exposed titanium implant surfaces.[24–29] For bone regeneration around transmucosal implants, osseointegration has not been documented. However, regeneration of the periodontal apparatus is predictably achieved around teeth in spite of the fact that they are transmucosal.[30] Numerous papers have been published documenting the intimate contact between the previously exposed root surface and the newly formed cementum with inserted collagen fibers. Based on these results from periodontal regeneration studies, previously exposed implant surfaces should be able to become osseointegrated in cases of transmucosal implant position during bone regeneration.

In a previous human study comparing bone fill in artificially prepared defects between a test group treated with an e-PTFE membrane and a control group treated without a membrane, better results were obtained in the membrane group.[31] These findings concur with results from other human and animal studies, where the control groups consistently failed to achieve results as good as those obtained in the test groups.[26,32] However, other investigators reported that undisturbed bone formation in fresh extraction sockets was excellent, so that only a few threads remained uncovered at the time of abutment connection of submerged immediate implants.[33] Nevertheless, considering the large defects in the present sample, it seemed unethical to include a control group treated without the use of a membrane.

The deepest defects in each patient in the present study were quite extensive, with an average of 8.4 mm and a range from 5 to 14 mm. The mean gain in bone height, 6.7 mm, ranging from 4 to 14 mm, was also very impressive. The mean fill of the defects with bone was 94%, which is in the upper range of the defect fill reported in earlier investigations. Previously, mean bone fill was reported to be 75%,[32] 90%,[10] 94%,[34] and 82%.[12] The variability in the percentage of defect fill in the present study, apart from the exposure complications in two patients, may have been caused by measurement errors or by displacement of the membrane both in the apical and coronal direction following initial measurements.

The mean distance from the implant shoulder to the crestal bone was 2.1 mm, which is somewhat less than the distance resulting from standard implantation procedures.[35] Under standard conditions of transmucosal implantation, the distance from the shoulder to the bone crest is 3.0 mm. The values found at the reentry surgery in the present study indicate that nearly 1 mm of the smooth surface of the neck portion of the implant was located subcrestally. Based on the findings from a recent clinical experiment, it may be anticipated that the bone located next to the smooth surface will be resorbed during the first year of implant function.[36]

In a recent animal experiment, e-PTFE membranes alone were shown to render the best bone quality in dehiscence-type defects around implants in fresh extraction sockets.[25] The only advantage of bone grafts in conjunction with membranes was a higher percentage of defect fill. Another study

reported no advantage in the use of demineralized freeze-dried bone allograft in conjunction with e-PTFE membranes over the use of membranes alone in defects similar to those found for the present study.[37] As indicated before, infection resulted in impaired clinical outcomes.

Presently, long-term data on the stability of regenerated bone around transmucosal implants are limited to two publications presenting results up to 2.5 years.[14,16] The peri-implant soft tissue conditions were healthy, and no clinically significant differences were found between the implants with the transmucosal regeneration and the control implants placed under standard transmucosal conditions.[16] The method of regeneration around transmucosal implants will be particularly beneficial when the combination of implantation and resorbable membranes can eliminate the need for a second surgical procedure.[38] However, further studies testing resorbable membranes are necessary before definitive recommendations can be made.

Conclusion

From the results of the present study, it is concluded that GBR and nonresorbable membranes involving immediate transmucosal implants can be successful in generating bone into peri-implant defects. The mean percentage of bone fill into the space bordered by the implant, the host bone of the alveolar socket, and the e-PTFE membrane amounted to 94%, although the extent of bone-implant contact in this area was unknown. These results appear to be at least partly caused by the closure of soft tissues against the implant surface, thus covering the membrane during the regenerative period. Based on these findings and the results from previous studies, the procedure of GBR involving transmucosal implants may be recommended for use in association with the immediate replacement of extracted teeth.

Acknowledgments

The investigators wish to express their special thanks to Dr Bettina Schlegel-Bregenzer and Dr Christian Tritten for expert treatment of patients included in the present study. This study was supported by the Clinical Research Foundation (CRF) for the Promotion of Oral Health, University of Bern, Bern, Switzerland.

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