Treatment of Peri-implantitis Using Guided Bone Regeneration and Bone Grafts, Alone or in Combination, in Beagle Dogs. Part 1: Clinical Findings and Histologic Observations

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The purpose of this study was to evaluate and compare the treatment of ligature-induced peri-implantitis using guided bone regeneration and two bone grafts alone and in combination. Mandibular premolars and first molars were extracted from four beagle dogs and after 3 months of healing, three Brånemark implants were placed on each side of the mandibles. Following abutment connection 3 months later, experimental peri-implantitis was induced by tying plaque-retentive ligatures around all abutments. Ligatures and abutments were removed after 3 months, and bony defects measured and treated with either: *(1)* debridement only; *(2)* debridement plus resorbable hydroxyapatite; *(3)* debridement plus canine freeze-dried demineralized bone; *(4)* debridement plus guided bone regeneration; *(5)* debridement plus resorbable hydroxyapatite and guided bone regeneration; or *(6)* debridement plus canine freeze-dried demineralized bone and guided bone regeneration. Pretreatment and 4-month-posttreatment comparison revealed a significant but variable degree of clinically appreciable hard tissue fill with all treatment procedures. Guided bone regeneration procedures resulted in the greatest fill, followed by bone grafts alone and flap debridement. There was no significant difference between guided bone regeneration and both guided bone regeneration/graft combinations; therefore, guided bone regeneration procedures appear to be a predictable treatment for plaque-induced peri-implant defects.
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Key words: bone grafts, bone regeneration, guided tissue regeneration, implantology, peri-implantitis, regeneration, wound healing

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The use of osseointegrated implants as abutments for fixed or removable prostheses has significantly increased during the last decade because of their excellent long-term prognosis.[1–4] Occasionally, however, peri-implant tissue destruction occurs during the implant-maintenance phase, resulting in the exposure of implant surfaces or threads previously embedded in bone. This peri-implant destruction is believed to result from the accumulation of pathogenic bacteria and has been termed "peri-implantitis" because of clinical, microbiologic, and histologic similarities to periodontitis.[5–9]

Advances in periodontal wound healing led to the concept of guided tissue regeneration.[10] This principle was originally developed to regenerate lost supporting structures around periodontitis-affected teeth and has recently been successfully applied during osseointegrated implant placement to regenerate bone around exposed implant surfaces.[11–18]

Because of these encouraging findings, the use of guided bone regeneration alone or in combination with bone grafts, such as resorbable hydroxyapatite or freeze-dried demineralized bone, has been advocated for the treatment of peri-implantitis.[19] At present, however, only two investigations have evaluated guided bone regeneration for the treatment of "plaque-affected" implants.[20,21] One of these studies[20] reported successful preliminary findings indicating new bone and reosseointegration around implants, whereas the other[21] failed to demonstrate any bone regeneration.

In addition to the remaining uncertainty about the predictability of guided bone regeneration for the treatment of peri-implant defects, to date there have been no controlled investigations evaluating the treatment of these defects with either guided bone regeneration, bone grafts, or the combination of both these treatment modalities. Therefore, it was the purpose of this study to evaluate and compare the treatment of ligature-induced peri-implantitis using either guided bone regeneration, two bone grafts alone, and the combination of guided bone regeneration with the two different graft materials independently.

Materials and Methods

Four 3-year-old beagle dogs were used in this investigation. The study outline is illustrated in Fig 1. For each experimental procedure, the animals were premedicated with ketamine and acepromazine. Surgical anesthesia was obtained by isoflurane gas intubation, supplemented with local administration of 2% Xylocaine (1:50,000 epinephrine) to reduce hemorrhage. At the beginning of the experiment, all mandibular premolar and first molar teeth were removed. After 3 months of healing (Fig 2a), full-thickness flaps were elevated, and three commercially available pure titanium implants (Brånemark System, Nobelpharma AB, Gothenburg, Sweden), 7 mm in length and 3.75 mm in diameter, were placed on each side of the mandibles (Fig 2b). The mucoperiosteal flaps were then repositioned and sutured.

Three months later, the implants were uncovered and titanium abutments were attached (Fig 3). Two weeks after the abutment connection, 4-0 silk ligatures were placed around each of the abutments (Fig 4), and the dogs were fed a soft diet to induce plaque accumulation and to provoke peri-implant inflammation and loss of bone.[7,9,21] Additional ligatures were placed over the previous ones and around the implants every 2 weeks. After 3 months, plaque accumulation and inflammation had significantly increased (Fig 5), and between 30% and 50% of the peri-implant bone had been lost (Fig 6). At this time, the ligatures were removed, and a plaque-control regime was initiated consisting of daily brushing with a fine flour of pumice combined with 0.12% chlorhexidine gluconate, followed by topical application of 0.12% chlorhexidine gluconate spray. In addition, systemic administration of metronidazole hydrochloride (250 mg once a day) was begun and maintained for 3 weeks.

After 2 weeks of this hygienic phase, full-thickness

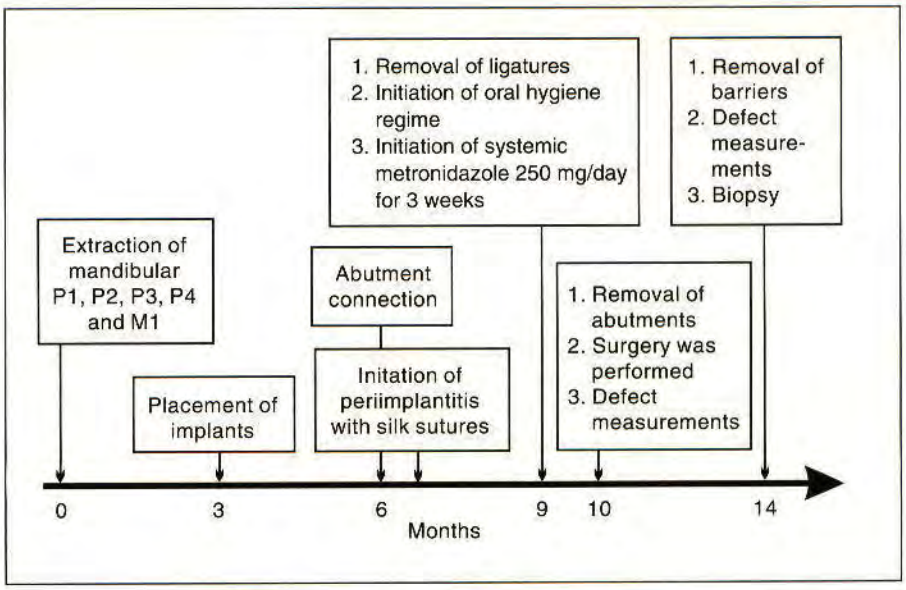

Fig 1 Study outline.

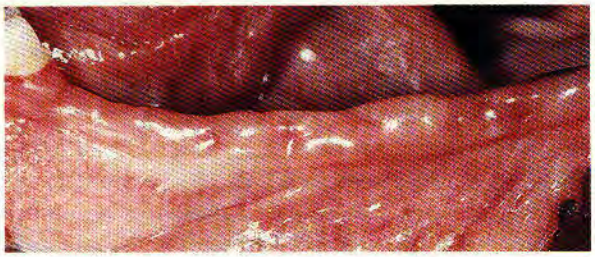

Fig 2a *(Above)* Clinical appearance of the edentulous ridge 3 months after extraction of the teeth.

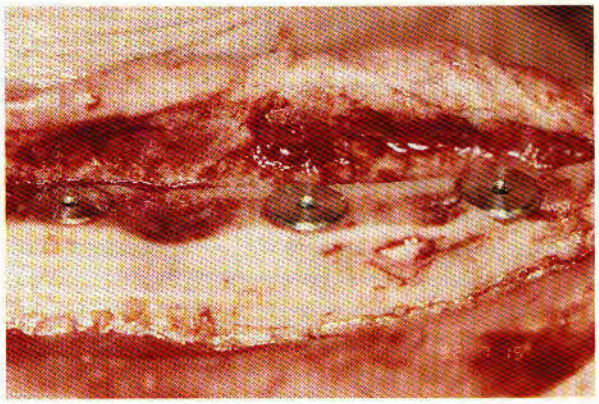

Fig 2b *(Right)* Appearance of the bony ridge with three Brånemark implants inserted.

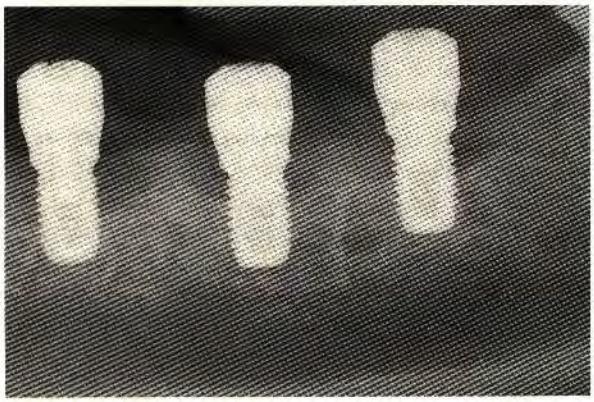

Fig 3 Radiograph depicting implant sites following a successful osseointegration healing period of 3 months and immediately after abutment connection.

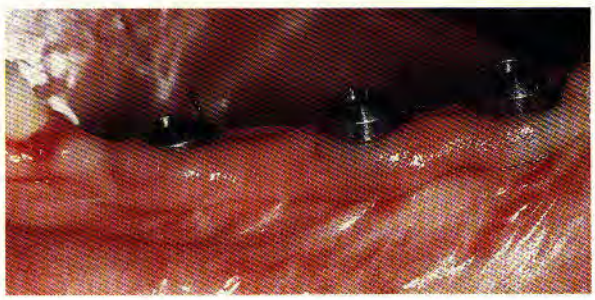

Fig 4 Clinical appearance of the peri-implant soft tissues immediately after placement of the first ligatures.

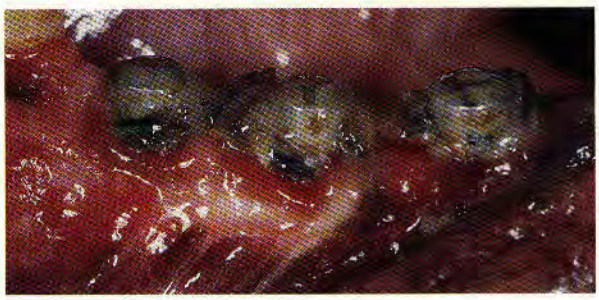

Fig 5 Appearance of the peri-implant soft tissues 3 months after initiation of experimental peri-implantitis.

flaps were reflected. The abutments were removed and the granulation tissue around the implants was carefully removed using hand curettes without touching the implant surface. The implant surfaces were then treated with an air-powder abrasive instrument (Prophy Jet, Dentsply, Encino, CA) for 30 seconds. At this time, clinical measurements of the peri-implant bony defects were recorded using a calibrated UNC-15 probe (Hu-Friedy, Chicago, IL). The distance from the top of the implant rim to the bottom of the defect was measured to the nearest millimeter around each implant in four sites (ie, middistal, midbuccal, midmesial, and midlingual). The bony defects resulting from the experimental peri-implantitis were in most instances wide and circumferential-infrabony in nature (Figs 7a and 8a).

Six different bony defect treatments were randomly assigned to each implant/dog prior to initiating the study and consisted of one of the following: *(1)* debridement only; *(2)* debridement plus resorbable hydroxyapatite (Osteogen, Stryker, Kalamazoo, MI); *(3)* debridement plus canine freeze-dried demineralized cortical bone (previously obtained from beagle dog femoral cortical bone and prepared according to standard human freeze-dried bone production procedures by Osteotech, Shrewsbury, NJ); *(4)* debridement plus guided bone regeneration using Gore-Tex Augmentation Material (GTAM, WL Gore, Flagstaff, AZ); *(5)* debridement plus resorbable hydroxyapatite and guided bone regeneration; or *(6)* debridement plus canine freeze-dried demineralized bone and guided bone regeneration. This experimental design provided a total of 24 implants (ie, four implants per treatment group) for statistical evaluation.

In those sites assigned to receive guided bone regeneration procedures, Oval-4 GTAM was trimmed and placed over the implant. The material was secured in place using the implant cover screw and extended 2 to 3 mm beyond the bony defect margins. In the sites treated with guided bone regeneration combined with one of the bone grafts, the graft was then moistened in sterile saline and carefully packed under the barrier and into the defect around the exposed implant threads. Miniature titanium pins were then placed to further secure the GTAM. Defects designated to receive bone graft alone were treated in the same manner, with the exception that no GTAM was placed. Peri-implant defects treated by flap debridement alone received no barrier or bone graft (Figs 7b and 8b).

After performing these treatments, the flaps were repositioned and sutured using interrupted mattress sutures. Systemic metronidazole administration was continued for the following week, and 0.12% chlorhexidine gluconate spray was topically applied for the next 3 weeks.

After a submerged healing period of 4 months, a flap was reflected, the GTAM were removed, and all supracrestal soft tissues were curetted. At this time, the peri-implant bony-defect measurements were retaken using the top of the implant rim as reference point. In one of the animals, a small tissue biopsy was taken from an adjacent interproximal area around each implant. The biopsies were fixed, decalcified, and paraffin embedded, using standard histologic methods. Specimens were thin-sectioned, mounted on glass slides, stained with both hematoxylin and eosin, and trichrome stains, and evaluated under light microscopy.

With regard to the statistical analyses, individual pretreatment and posttreatment clinical measurements from the four sites around each implant were averaged to obtain a mean value for the defect. Two-way analysis of variance (ANOVA) was then performed for the pretreatment and posttreatment mean values, and for the change in hard tissue fill between the two examinations. Two-way ANOVA permitted comparison of the six treatments within an animal. If significant treatment differences were detected, a Scheffe's multiple comparison was performed. Changes in hard tissue fill between the pretreatment and posttreatment examinations were also analyzed by Student's t test. The variable analyzed was the difference between mean measurements for each defect within a treatment group.

Results

Clinical Findings. Clinical signs of peri-implant inflammation were minimal after 2 weeks of plaque control and systemic metronidazole administration. Postoperative healing following peri-implant defect treatment progressed uneventfully. All implant sites in the four animals remained completely submerged, and none of the guided bone augmentation materials became exposed. Newly regenerated hard tissue, clinically resembling normal bone, was evident around all implants at the 4-month reentry examination (Figs 7c and 8c). An obvious gain in the width of the alveolar ridge was observed only in those sites treated with guided bone regeneration procedures (Fig 9). This increase in ridge width corresponded to the location and extent of the GTAM.

Analyses of the pretreatment peri-implant defect measurements revealed no initial differences in defects between and within animals (ie, at baseline, all defects were similar) (Table 1). Comparison between pretreatment and posttreatment measurements revealed a significant, but variable, degree of clinically appreciable hard tissue fill with all treatment procedures, including flap debridement alone (Table 1 and Fig 10). Guided bone regeneration procedures resulted in the greatest fill, followed by bone grafts alone, and then flap debridement. Of the guided bone regeneration procedures, the combination with canine freeze-dried demineralized bone resulted in the most fill, followed by guided bone regeneration alone, and then by guided bone regeneration with resorbable hydroxyapatite, but these were not significantly different from each other. Of the bone grafts, freeze-dried demineralized bone resulted in a greater fill than with resorbable hydroxyapatite. However, there was no significant difference in fill between the two graft materials. Resorbable hydroxyapatite resulted in a greater fill than flap debridement alone, but this was not significant.

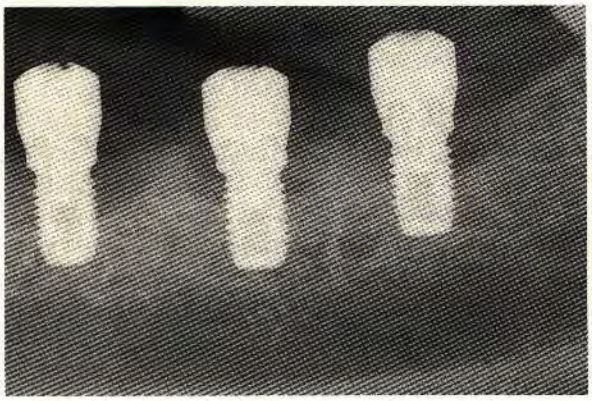

Fig 6 Radiograph depicting implant sites and peri-implant bone loss 3 months after initiation of experimental peri-implantitis.

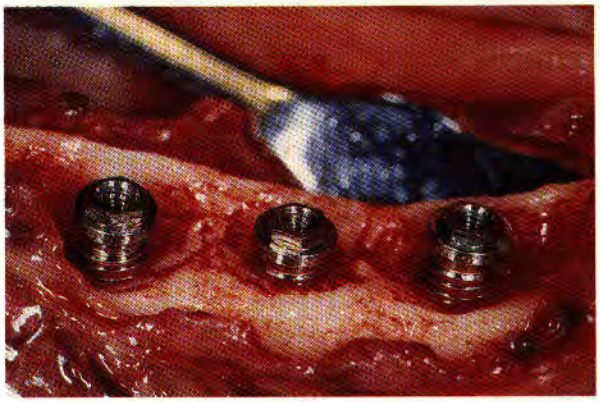

Fig 7a Appearance of the defects after flap elevation and debridement. The defects were wide, circumferential, and infrabony.

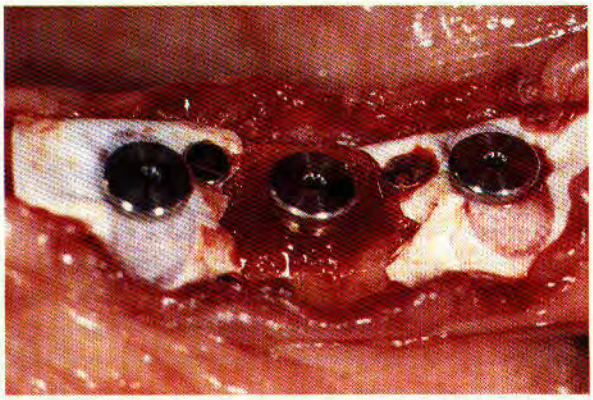

Fig 7b Gore-Tex Augmentation Material (GTAM) was placed over the left and right implants and secured in place with the cover screws and miniature pins. The defect on the left was treated with guided bone regeneration alone. The middle defect was treated with flap debridement alone, and the defect on the right with guided bone regeneration and freeze-dried bone allograft.

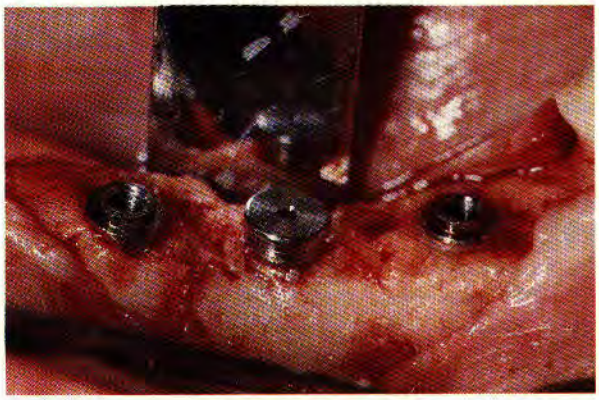

Fig 7c Appearance of the defects after flap elevation and barrier removal at the 4-month reentry examination. Significant bone fill is apparent on both of the guided bone regeneration–treated defects *(left, right),* while only a slight fill is noted on the defect treated with flap debridement alone *(middle).*

Histologic Observations. The tissue biopsy specimen obtained from the implant site treated by flap debridement alone was characteristic of healthy peri-implant connective tissue (Fig 11). Collagenlike fibers were arranged in a parallel array, and numerous fibroblasts were present. Minimal inflammatory cells were observed, and there was no bone present.

The biopsy specimen taken from the site treated with resorbable hydroxyapatite alone demonstrated an appearance similar to that of the flap-debridement specimen, with the exception that a few hydroxyapatite particles were present embedded in the connective tissue (Fig 12).

All tissue biopsy specimens taken from the remaining four treatments (guided bone regeneration alone, the two guided bone regeneration/graft combinations, and freeze-dried demineralized bone alone) indicated new bone formation in different stages of maturation (Figs 13a and 13b). The new bone was mostly lamellar and compact, and numerous osteocytes were present in their lacunae.

Discussion

Results of the present investigation support the use of guided bone regeneration for the treatment of bony defects created by peri-implantitis. This is not in

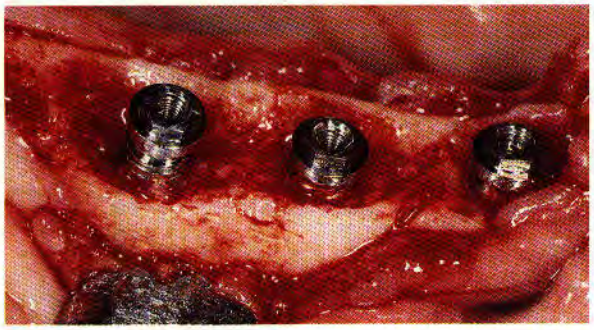

Fig 8a Appearance of the defects after flap elevation and debridement.

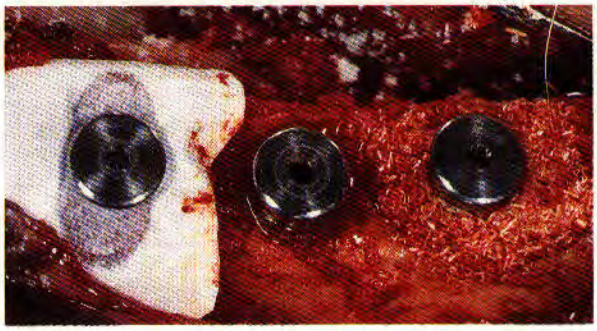

Fig 8b The defect on the left was treated with guided bone regeneration and freeze-dried bone allograft. The middle defect was treated with flap debridement alone. The defect on the right was treated with resorbable hydroxyapatite alone.

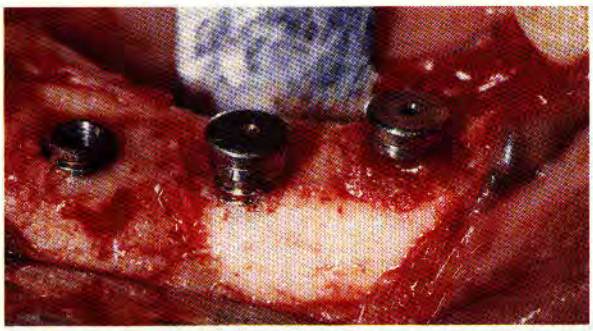

Fig 8c *(Above)* Appearance of the defects after flap elevation and barrier removal at the 4-month reentry examination. Significant bone fill is apparent on the defect treated with guided bone regeneration in combination with freeze-dried bone allograft *(left)*. The defect treated with resorbable hydroxyapatite demonstrated an intermediate fill *(right)*, and a slight fill is noted on the defect treated with flap debridement alone *(middle)*.

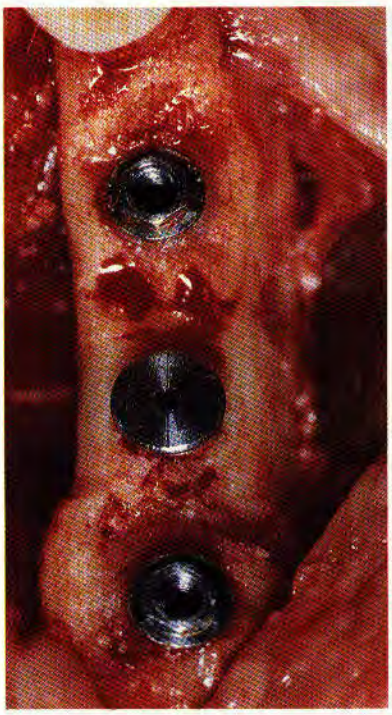

Fig 9 *(Right)* Occlusal view of the alveolar ridge in Fig 7c at the 4-month reentry examination. Sites treated with guided bone regeneration procedures exhibited an apparent increase in buccolingual ridge width, corresponding to the location and extent of the GTAM.

agreement with the findings recently published by Grunder and coworkers,[21] who were not successful in treating peri-implantitis with guided bone regeneration. However, there were two important differences between that study and the present investigation. First, the peri-implant bony defects created in Grunder et al's study were ligature-induced, chronic, horizontal-type defects. This defect morphology could have resulted from placing the implants at the recommended distance between implants of 3.5 mm.[22] In the present experiment, implants were placed at a distance of at least 7 mm from each other. After 3 months of plaque accumulation, this resulted in chronic, circumferential peri-implant defects. It is well-known that circumferential infrabony defects around teeth have a greater potential for regeneration than horizontal defects. Therefore, it is likely that a similar healing response would occur in a peri-implant bony defect. A second major difference between the two studies is that in the Grunder et al investigation,[21] the guided bone regeneration barriers became exposed as early as 1 week and were all

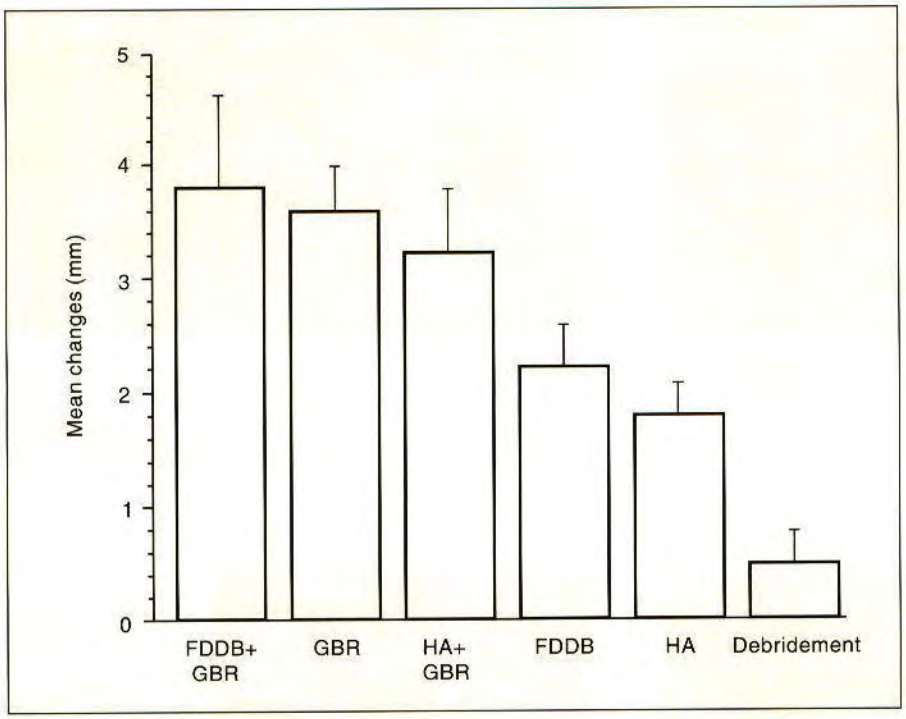

Fig 10 Hard tissue changes between the baseline and 4-month reentry examinations. (FDDB = canine freeze-dried demineralized bone; GBR = guided bone regeneration; HA = resorbable hydroxyapatite.)

Table 1 Comparison Between and Within Treatments for Hard Tissue Fill Measurements (mm)

	Pretreatment (mean ± SD)	Posttreatment (mean ± SD)	Δ values (mean difference ± SD)	Student's *t* test	*P* value
FDDB + GBR	4.2 ± 1.0	0.4 ± 0.3	3.8 ± 0.8	9.23	0.0027
GBR	3.9 ± 0.1	0.3 ± 0.2	3.6 ± 0.4	19.0	0.0003
HA + GBR	3.4 ± 0.8	0.2 ± 0.3	3.2 ± 0.6	11.04	0.0016
FDDB	3.8 ± 0.5	1.6 ± 0.3	2.2 ± 0.4	11.55	0.0014
HA	3.4 ± 0.5	1.6 ± 0.3	1.8 ± 0.3	13.93	0.0008
Debridement	3.5 ± 1.0	3.0 ± 0.9	0.5 ± 0.3	3.4	0.0425

	F value	Pr > F
Pretreatment	0.79	0.5736
Dog	0.75	0.5411
Posttreatment	25.46	0.0001
Dog	1.61	0.2288
Δ values	23.54	0.0001
Dog	0.52	0.6728

Mean values within brackets are not significantly different; Scheffe comparison, $P < .05$.
FDDB = canine freeze-dried demineralized bone; GBR = guided bone regeneration; HA = resorbable hydroxyapatite.

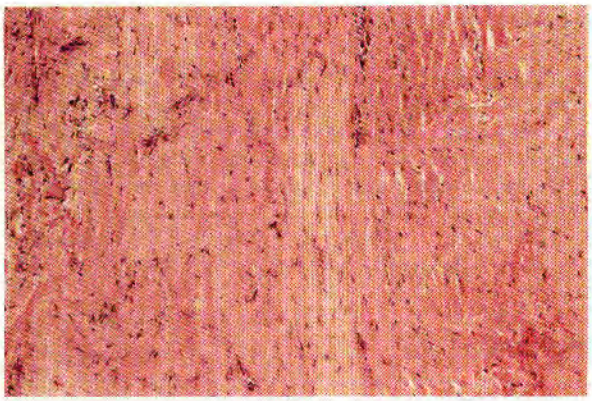

Fig 11 Biopsy specimen from an implant site treated by flap debridement alone demonstrating healthy peri-implant connective tissue. (Original magnification × 100; hematoxylin and eosin stain.)

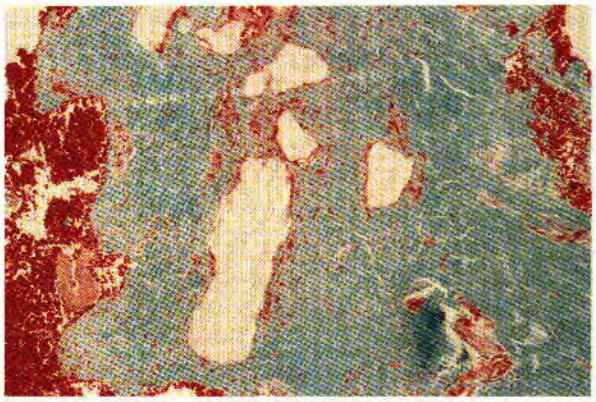

Fig 12 Biopsy specimen from an implant site treated with flap debridement and resorbable hydroxyapatite *(arrows)* showing graft particles embedded in healthy connective tissue. (Original magnification × 100; trichrome stain.)

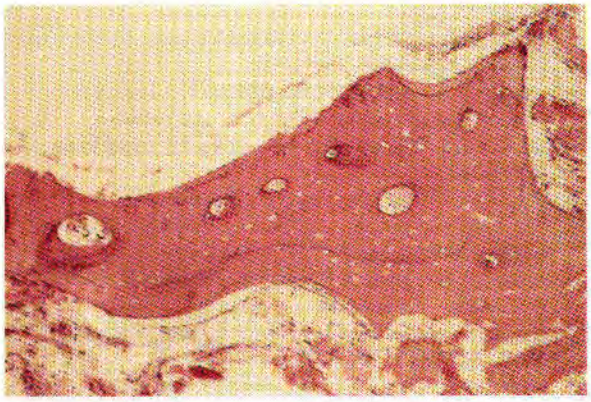

Fig 13a Biopsy specimen from an implant site treated with guided bone regeneration alone, showing new bone formation. (Original magnification × 100; hematoxylin and eosin stain.)

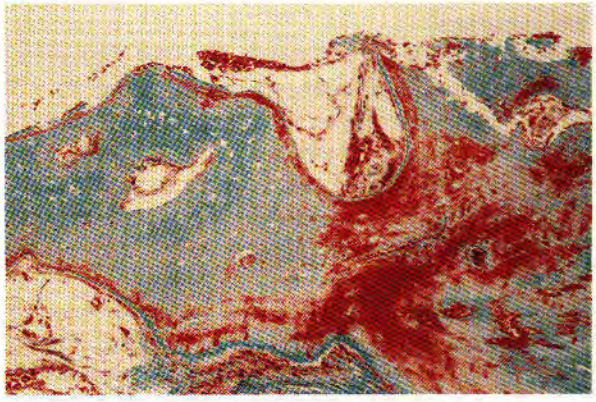

Fig 13b Biopsy specimen from an implant site treated with guided bone regeneration and freeze-dried bone allograft, showing bone formation. (Original magnification × 100; trichrome stain.)

removed by 1 month. In the present report, all barriers remained completely covered by soft tissue, and were not removed until their scheduled time 4 months after surgery. Therefore, defect morphology and maintenance of the barrier in an undisturbed, plaque-free, submerged position for a determined amount of time appear to be of critical importance for the success of guided bone regeneration procedures.

In a recent preliminary report,[20] peri-implant defects in three beagle dogs were successfully treated with guided bone regeneration. In that report, however, a surgical bur was first used to enlarge the coronal portion of the implant osteotomies. A ligature was then tied around the coronal 3- to 4-mm portion of the implants immediately prior to their placement, and after placement, the flaps were repositioned. After an osseointegration period of 3 months, a flap was reflected, the ligatures were removed, and the defects treated. Such an experimental model, therefore, resembles more an acute peri-implant abscess than chronic peri-implantitis.

In the present study, the animal model used by Grunder and colleagues,[21] as well as others,[7,9] was

chosen to simulate the clinical conditions of peri-implantitis as they occur in humans. In this model, implants were placed according to standard protocol and were allowed an osseointegration period. After successful osseointegration, abutment connection was performed, ligatures were placed around the abutments, and the animals were fed a soft diet to induce plaque accumulation. This provoked plaque-induced peri-implant inflammation and progressive loss of implant-supporting bone, and appears to closely resemble true peri-implantitis.[7,9,23–25]

The present investigation is the first evaluating and comparing the treatment of plaque-induced peri-implantitis using either guided bone regeneration, bone grafts alone, or the combination of guided bone regeneration with bone-graft materials. A hygienic phase that included systemic antimicrobial administration was used. The use of this antimicrobial, in combination with daily oral hygiene, resulted in a significant reduction of clinical signs of peri-implant inflammation.

Results from the biometric analyses indicated a significant but variable degree of hard tissue fill with all treatment procedures, including flap debridement alone. As previously mentioned, the peri-implant defects created in the present study were circumferential and infrabony. Therefore, it was not surprising to find a significant fill in those sites treated with flap debridement alone, since a similar healing response occurs around teeth with circumferential defects.[26,27]

When comparing the use of bone grafts, freeze-dried demineralized bone resulted in a significantly greater defect fill than that observed with resorbable hydroxyapatite. This could be explained by a possible osteoinductive effect of the freeze-dried bone allograft.[28–31]

Conclusion

Of all the treatment approaches evaluated, guided bone regeneration procedures resulted in the greatest hard tissue fill. Since there was no significant difference between guided bone regeneration and the guided bone regeneration/graft combinations, it appears that all guided bone regeneration procedures can be a predictable treatment for plaque-induced peri-implant defects. This is also supported by the histologic evidence of new bone found in the tissue biopsies from sites treated with guided bone regeneration. However, further controlled histologic investigations evaluating the implant–regenerated tissue interface, as well as clinical trials in humans, are needed to confirm the predictability of guided bone regeneration procedures for the treatment of peri-implantitis.

Acknowledgments

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References

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–415.
2. Linquist L, Carlsson G, Glantz PO. Rehabilitation of the edentulous mandible with a tissue-integrated fixed prosthesis: A six-year longitudinal study. Quintessence Int 1987;18:89–96.
3. Zarb GA, Symington J. Osseointegrated dental implants: Preliminary report on a replication study. J Prosthet Dent 1982;50:271–276.
4. Patrick D, Zosky J, Lubar R, Buchs A. The longitudinal clinical efficacy of Core-Vent dental implants: A 5-year report. J Oral Implantol 1989,15:95–103.
5. Mombelli A, van Osten MAC, Schürch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987;2:145–151.
6. Mombelli A, Buser D, Lang NP. Colonization of osseointegrated titanium implants in edentulous patients. Early results. Oral Microbiol Immunol 1988;3:113–120.
7. Lindhe J, Berglundh T, Ericsson I, Liljenberg B, Marinello C. Experimental breakdown of peri-implant and periodontal tissues. A study in the beagle dog. Clin Oral Implants Res 1992;3:9–16.
8. Quirynen M, Listgarten MA. Distribution of bacterial morphotypes around natural teeth and titanium implants ad modum Brånemark. Clin Oral Implants Res 1990;1:8–12.
9. Strub JR. Langzeitprognose von enossalen oralen Implantaten unter spezieller Berücksichtigung von periimplantären, materialkundlichen und okklusalen Gesichtspunkten. Berlin: Quintessenz, 1986:65–90.
10. Caffesse RG, Quiñones CR. Guided tissue regeneration: Biologic rationale, surgical technique, and clinical results. Compend Contin Educ Dent 1992;13:166–178.
11. Dahlin C, Sennerby L, Lekholm U, Linde A, Nyman S. Generation of new bone around titanium implants using a membrane technique: An experimental study in rabbits. Int J Oral Maxillofac Implants 1989;4:19–25.
12. Becker W, Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: Surgical techniques and case reports. Int J Periodont Rest Dent 1990;10:376–391.
13. Becker W, Becker BE, Handlesman M, Celletti R, Ochsenbein C, Hardwick R, Langer B. Bone formation at dehisced dental implant sites treated with implant augmentation material: A pilot study in dogs. Int J Periodont Rest Dent 1990;10:93–101.
14. Nyman S, Lang NP, Buser D, Brägger U. Bone regeneration adjacent to titanium dental implants using guided tissue regeneration: A report of two cases. Int J Oral Maxillofac Implants 1990;5:9–14.

15. Günay H, Skuballa C, Neukamm FW. Experimentelle Untersuchung zur Behandlung von periimplantären Knochendefekten. Z Zahnärztl Implantol 1991;7:16–24.
16. Jovanovic SA, Spiekermann H, Richter E-J. Bone regeneration around titanium dental implants in dehisced defect sites: A clinical study. Int J Oral Maxillofac Implants 1992; 7:233–245.
17. Hürzeler MB, Quiñones CR. Installation of endosseous oral implants with guided tissue regeneration. Pract Periodont Aesth Dent 1991;3:21–29.
18. Lazzara RJ. Immediate implant placement into extraction sites: Surgical and restorative advantages. Int J Periodont Rest Dent 1989;9:333–343.
19. Meffert RM. How to treat failing implants. Implant Dent 1992;1:25–33.
20. Jovanovic SA, Kenney EB, Carranza FA Jr, Donath K. The regenerative potential of plaque-induced peri-implant bone defects treated by a submerged membrane technique: An experimental study. Int J Oral Maxillofac Implants 1993;8:13–18.
21. Grunder U, Hürzeler MB, Schüpbach P, Strub JR. Treatment of ligature-induced peri-implantitis using guided tissue regeneration. A clinical and histological study in the beagle dog. Int J Oral Maxillofac Implants 1993;8:282–293.
22. Adell R, Lekholm U, Brånemark P-I. Surgical procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds.) Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:211–232.
23. Lang NP, Brägger U, Walther D, Beamer B, Kornman KS. Ligature-induced peri-implant infection in cynomolgus monkeys. I. Clinical and radiographic findings. Clin Oral Implants Res 1993;4:2–11.
24. Lang NP, Holt SC, Brandes R, Brägger U, Stich H, Kornman KS. Ligature-induced peri-implant infection in cynomolgus monkeys. II. Microbiologic and histologic findings. Clin Oral Implants Res 1995 (in press).
25. Schou S, Holmstrup P, Stoltze K, Hjørting-Hansen E, Kornman KS. Ligature-induced marginal inflammation around osseointegrated implants and ankylosed teeth. Clinical and radiographic observations in cynomolgus monkeys (*Macaca fascicularis*). Clin Oral Implants Res 1993;4:12–22.
26. Polson AM, Heijl LC. Osseous repair in infrabony periodontal defects. J Clin Periodontol 1978;5:13–23.
27. Becker W, Becker BE, Berg L, Samsam C. Clinical and volumetric analysis of three-wall intrabony defects following open flap debridement. J Periodontol 1986;57:277–285.
28. Urist MR. Bone formation by autoinduction. Science 1965;150:893–899.
29. Urist MR, Dowell TA, Hay PH, Strates BS. Inductive substrates for bone formation. Clin Orthop 1968;59:59–96.
30. Urist MR, Dowell TA. Inductive substratum for osteogenesis in pellets of particulate bone matrix. Clin Orthop 1968; 61:61–78.
31. Harakas N. Demineralized bone-matrix-induced osteogenesis. Clin Orthop 1984;188:239–251.

Résumé

Traitement de la péri-implantite à l'aide de régénération tissulaire guidée et de greffes osseuses, séparement ou en combinaison, chez les chiens Beagle. Part 1: Résultats cliniques et observations histologiques

Le but de cette étude fut d'évaluer et comparer le traitement de la péri-implantite induite par ligature à l'aide de régénération tissulaire guidée et de deux greffes osseuses séparement ou en combinaison. Les prémolaires mandibulaires et les premières molaires furent extraites sur quatre chiens Beagle. Après 3 mois, trois implants Branemark furent placés de chaque coté de la mandibule; 3 mois plus tard, les piliers furent reliés à chaque implant et les péri-implantites expérimentales furent induites en nouant des ligatures retenant la plaque autour de tous les piliers. Aprés 3 mois, les ligatures furent enlevées et un régime journalier de controle de plaque fut instauré. Les défauts osseux furent ensuite mesurés àl'aide d'une sonde calibrée et traités soit à l'aide de: *(1)* débridement seul; *(2)* débridement plus hydroxyapatite résorbable; *(3)* débridement plus os déminéralisé lyophilisé canin; *(4)* débridement plus régénération tissulaire guidée (à l'aide de membrane d'augmentation Gore-Tex); *(5)* débridement plus hydroxyapatite résorbable et régénération tissulaire guidée; ou *(6)* débridement plus os déminéralisé lyophilisé canin et régénération tissulaire guidée. Les lambeaux furent ensuite repositionnés et suturés. Les comparaisons entre pré et post traitements révélèrent un degré appréciable de comblement des tisssu durs significatif mais variable pour toutes les modalités de traitement. Les techniques de régénération tissulaire guidée donnèrent le meilleur comblement suivi des greffes osseuse seules et du débridement du lambeau. Il n'y eut pas de différence significative entre la régénération tissulaire guidée et à la fois les combinaisons de régénération guidée et de greffes osseuses; donc les techniques de régénération guidé semblent offrir une option prévisible en vue du traitement des défauts osseux péri-implantaires induits par la plaque.

Zusammenfassung

Behandlung von plaqueinduzierten periimplantären Knochendefekten mit Hilfe der gesteuerten Knochenregeneration und/oder Knochenaufbaumaterialien im Hundemodell. Teil 1: Klinische und histologische Ergebnisse

Ziel der vorliegenden Studie war ein Vergleich zwischen der gesteuerten Knochenregeneration (GKR), zwei verschiedenen Knochenaufbaumaterialien, und deren Kombination zur Behandlung von plaqueinduzierten periimplantären Knochendefekten. Bei vier Beagle-Hunden wurden alle Prämolaren und ersten Molaren im Unterkiefer entfernt. Nach drei Monaten wurden beidseitig jeweils drei Branemark-Implantate eingebracht. Drei Monate danach wurde während der Implantateröffnung durch plaqueretentive Ligaturen im Bereich der Einheilungsschrauben experimentell Periimplantitis erzeugt. Die Ligaturen wurden nach drei Monaten entfernt und eine tägliche Plaquekontrolle begonnen. Metronidazol wurde systemisch für drei Wochen verabreicht. Die Knochendefekte wurden mit einer geeichten Parodontalsonde gemessen und danach auf verschiedene Weise therapiert: *(1)* Defektreinigung alleine; *(2)* Defektreinigung und Augmentation mit resorbierbarem Hydroxylapatit (HA); *(3)* Defektreinigung und Augmentation mit gefriergetrocknetem demineralisiertem Hundeknochen; *(4)* Defektreinigung in Verbindung mit GKR (Gore-Tex Augmentationsmaterial); *(5)* Defektreinigung, GKR und resorbierbares HA; *(6)* Defektreinigung, GKR und gefriergetrockneter demineralisierter Knochen. Die Lappen wurden danach reponiert und vernäht. Ein klinischer Vergleich der präoperativen und postoperativen Knochendefekte ergab eine signifikante jedoch mit der Behandlungsmethode variierende Defektauffüllung mit harten Gewebe. Die mit GKR behandelten Defekte zeigten eine zum Teil vollständige Auffüllung, gefolgt von den Knochenaufbaumaterialien und der Defektreingung. Es ergab sich jedoch kein signifikanter Unterschied zwischen GKR und GKR in Verbindung mit Knochenaugmentationsmaterialien. Daher erscheint die GKR die erfolgsversprechendste Therapie zur Behandlung von plaqueinduzierten periimplantären Knochendefekten zu sein.

Resumen

El Tratamiento de la Peri-implantitis en Perros Sabuesos Por Medio de la Regeneración Osea Guiada e Injertos Oseos Solos o Combinados. 1a Parte: Hallazgos Clínicos y Observaciones Histológicas.

El propósito de este estudio fue el de evaluar y comparar el tratamiento de la peri-imiplantitis (inducida por medio de ligaduras), utilizando la regeneración ósea guiada (ROG) y dos injertos óseos solos o en combinación. Los premolares y primeros molares inferiores fueron extraídos de cuatro perros sabuesos. Después de 3 meses, se colocaron tres implantes Brånemark en cada sitio correspondiente a los dientes extraídos; 3 meses mas tarde, los pilares fueron conectados a cada implante y se indujo una peri-implantitis experimental amarrando ligaduras que acumulaban placa alrededor de todos los pilares. Después de 3 meses, se quitaron las ligaduras y se inició un control de placa diario. Los defectos óseos fueron medidos utilizando una sonda calibrada y fueron luego tratados con uno de los siguientes métodos: *(1)* desbridamiento sólo; *(2)* desbridamiento mas hidroxiapatita reabsorbible; *(3)* desbridamiento mas hueso canino desmineralizado y deshidratado por congelación; *(4)* desbridamiento mas el tratamiento a base de ROG (utilizando el Material de Aumento Gore-Tex); *(5)* desbridamiento mas hidroxiapatita reabsorbible y ROG; ó *(6)* desbridamiento mas hueso canino desmineralizado y deshidratado por congelación y ROG. Los colgajos fueron luego reposicionados y suturados. Cuatro meses después de la cirugía, el material Gore-Tex fue retirado y se midieron los defectos. Al comparar los diferentes tratamientos antes y después se determinó clínicamente que existía una cantidad de relleno tisular duro apreciable, pero variable en todos los tratamientos. Los procedimientos a base de ROG produjeron los mayores rellenos, seguidos por los injertos óseos solos y el desbridamiento. No se determinó una diferencia significativa entre la ROG y la combinación de ROG mas injerto; por lo tanto la ROG parece ser el tratamiento mas predecible para los defectos peri-implantares inducidos experimentalmente por medio de placa.