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The jumping distance revisited

An experimental study in the dog

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Abstract: Following tooth extraction, a socket often presents dimensions that may be considerably greater than the diameter of a conventional implant. The present experiment was performed to study the healing that occurred adjacent to implants placed in recipient sites with a wide marginal defect. Four Labrador dogs were used. In the right side of the mandible, four experimental sites were prepared to receive titanium implants [sandblasted, large-grit, acid-etched (SLA) surface]. Traditional implant installation (control) was performed in one site. In the remaining three sites (test), a step drill was used to widen the marginal 5 mm of the canal. Following placement of an implant in a test site, a circumferential gap about 1–1.25 mm wide and 5 mm deep was present lateral to the implant. A resorbable barrier membrane was used to cover the implant and the bone tissue of two sites, while one site was left uncovered. Four months following implant installation, block biopsies of each implant site were obtained and prepared for ground sectioning. After 4 months of healing, the large marginal defect had been filled with newly formed bone. The degree of bone-to-implant contact between the newly formed tissue and the SLA surface was at all test sites high and similar to that obtained at control sites. The placement of a barrier membrane following implant installation did not improve the outcome of healing. We conclude that a marginal defect wider than 1 mm may heal with new bone and a high degree of osseointegration to an implant designed with a SLA surface.

The placement of implants in fresh extraction sockets was advocated by many authors as a means of reducing the time required for rehabilitation (Lazzara 1989; Becker & Becker 1990; Nyman et al. 1990; Gelb 1993; Gher et al. 1994; Lang et al. 1994; Brägger et al. 1996; Rosenquist & Grenthe 1996; Schwartz-Arad & Chaushu 1997; Becker et al. 1998; Grunder et al. 1999; Nemcovsky et al. 1999). Findings from animal studies suggested that proper osseointegration may occur to implants placed in such fresh extraction sockets (Anneroth et al. 1985; Becker et al. 1991; Warrer et al. 1991; Lundgren et al. 1992;

Gotfredsen et al. 1993, 1994; Parr et al. 1993; Barzilay et al. 1996a,b; Kohal et al. 1997; Alliot et al. 1999; Karabuda et al. 1999).

Following tooth extraction, however, a socket often presents dimensions that may be considerably greater than the diameter of a conventional implant. Hence, following implant installation a gap may occur in the marginal part of the recipient site. An experiment on total hip arthroplasty in dogs suggested that (i) a close fit between the recipient site and the implant was of critical importance for proper osseointegration, and (ii) a gap between the bone and the im-

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Fig. 1. The step drill used to prepare the defects at the test sites. The diameter of the upper, cutting part of the drill was 5.3 mm.

plant of 0.5 mm compromised the establishment of acceptable bone-to-implant contact (Harris et al. 1983).

Schenk & Willenegger (1977), in a study in the rabbit, suggested that comprehensive bone bridging, i.e. the rapid formation of woven bone that occurs to close a defect, is dependent on the size of the void. Thus, if the size of a defect is greater than 1 mm, bridging may become incomplete.

The validity of this conclusion was demonstrated by Carlsson et al. (1988). They used a rabbit model and placed implants in recipient sites that provided gaps of varying size (group A = 0 mm; group B = 0.35 mm; group C = 0.85 mm) between the implant and the host bone. In biopsies obtained after 6 and 12 weeks of healing it was observed that residual gaps (between 0.22 and 0.54 mm in width) occurred both in group B and in group C.

Caudill & Meffert (1991) studied gap healing next to implants in a dog model. The recipient sites were widened in the marginal portion of the canal in the bone. Following implant installation the distance – in the marginal 4 mm of the recipient site – between the bone tissue and the titanium surface was approximately 1 mm. In biopsies obtained after 9 weeks of healing, it was observed that hard tissue healing was compromised and the bone-to-implant contact in the marginal portion of the implant bed was incomplete.

Knox et al. (1991), in another dog model, studied bone formation and the closure of gaps following implant installation. After

the preparation of the implant bed, the marginal 4 mm of the site was enlarged. Thus, following implant installation, a gap between 0.5 and 2 mm wide occurred between the titanium surface and the bone. The implants were fully submerged and no membrane was used to guard the defect. Healing was allowed and biopsies obtained after 8 weeks. Measurements performed in the sections revealed that the coronal level of bone-to-implant contact was influenced by the presence of a gap in the marginal portion of the implant site. Thus, if following the insertion of the implant a marginal gap >0.5 mm wide occurred, the level of bone-to-implant contact was established at a more apical level than in control sites where no defect had been produced.

Akimoto et al. (1999) used a dog model to evaluate the bone fill that occurred in defects adjacent to implants designed with a machined surface. Implants were placed in simulated extraction sockets that had been prepared in such a way that gaps of between 0.5 and 1.4 mm separated the implant surface and the bone. A clinical examination performed after 12 weeks of healing showed that all defects, independent of size, had healed properly. Histological measurements made in biopsies obtained from the different defect sites, however, revealed that there was consistently a certain distance between the marginal border of the implant and the most coronal level of bone-to-implant contact. Further, it was observed that this distance varied with the initial size of the defect. Thus, the wider the defect, the longer the distance between the rim of the implant and the level of bone-to-implant contact.

In contrast, recent findings from our laboratory (Persson et al. 1999, 2001a,b) and by Wetzel et al. (1999) have suggested that bone fill following treatment of ligature-induced peri-implantitis in dogs may also occur in deep and wide defects in the marginal region of a titanium implant.

The aim of the present experiment was to further study (i) the amount of new bone forming adjacent to implants placed in recipient sites with a wide marginal defect and (ii) the degree of bone-to-implant contact occurring in such a site.

Material and methods

Four Labrador dogs, about 1 year old, were used. The study protocol was approved by the Regional Ethics Committee for Animal Research. During surgical procedures the animals were first given atropine (0.05 mg/kg subcutaneously) and thiopentone (2.5% solution, 20 mg/kg intravenously). An endotracheal tube was subsequently used for intubation, and a gas mixture of halothane (0.5–2.0%) and N₂O:O₂ (1:1) was administered.

In each dog the mandibular premolars and 1st molars were extracted. After 3 months of healing, defect preparation and implant installations were performed in the right side of the mandible.

Following a crestal incision on the right side of the mandible, buccal and lingual full-thickness mucoperiosteal flaps were elevated. The alveolar processes of the four experimental sites were prepared to receive custom-made titanium implants (Straumann AG, Waldenburg, Switzerland; diam-

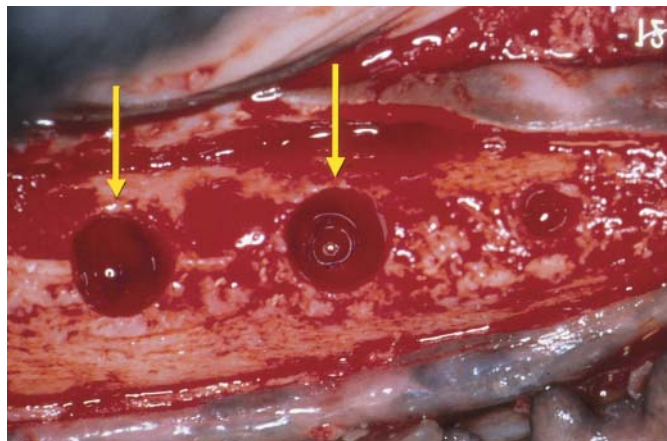


Fig. 2. Clinical photograph illustrating two test sites (arrows) and one control site. Note the wide marginal defect in the test sites.

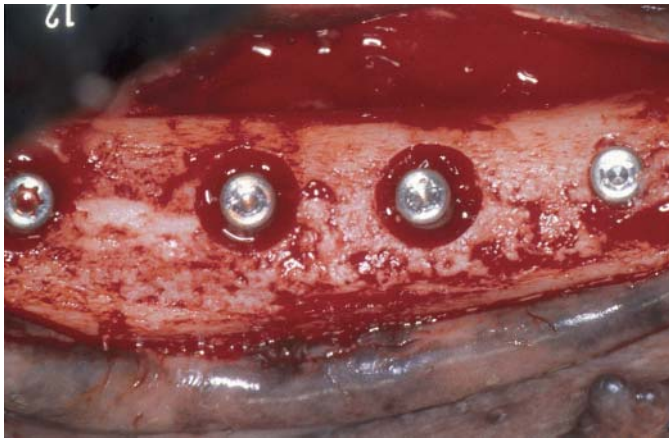


Fig. 3. Clinical photograph illustrating three test sites, with wide marginal defects, and a control site. Note the wide circumferential defects in the test sites.

eter = 3.3 mm; length = 10 mm) designed with a sandblasted, large-grit, acid-etched (SLA) surface. The surgical preparation was performed according to the manual of the ITI® system (Straumann, Waldenburg, Switzerland).

Traditional implant installation (control) was performed in one site (R_1). In the remaining three sites (R_2 , R_3 and R_4 ; test), a specially designed step drill (Fig. 1) was used to widen the marginal 5 mm of the canal (Fig. 2). Thus, following the placement of the implant in a test site, a circumferential gap (Figs 3 and 4) about 1–1.25 mm wide and 5 mm deep was present lateral to the titanium rod.

Titanium healing caps were attached to all implants. A resorbable bilayer barrier membrane (Bio-Gide®, Geistlich AG, Wolhusen, Switzerland) was used to cover the implant and the bone tissue of sites R_3 and R_4 while site R_2 was left without a membrane cover.

The mucoperiosteal flaps were replaced and sutured to ensure that the implants in the test and control sites were properly submerged. After 2 weeks the sutures were removed.

Four months following the implant installation procedure, the animals were sacrificed with an overdose of pentothal sodium (Abbot Laboratories, Chicago, IL) and were perfused with a fixative (Karnovsky 1965) through the carotid arteries. The mandibles were removed and block biopsies of each implant site were dissected using a diamond saw (Exakt®, Apparatebau, Norderstedt, Germany) and placed in the fixative.

The tissue blocks were prepared for

ground sectioning according to Donath & Breuner (1982) and Donath (1988). The specimens were dehydrated in ethanol, embedded in methacrylate (Technovit® 7200 VLC, Kulzer, Friedrichsdorf, Germany), and cut in one mesio-distal and one buccal-lingual plane using a diamond saw (Exakt®, Apparatebau, Norderstedt, Germany). From each implant site, two central sections, from both the bucco-lingual and the mesio-distal planes, were harvested and reduced to a final thickness of about 20 µm by microgrinding and polishing using a cutting-grinding device (Exakt®). The sections were stained in toluidine blue (Donath 1993).

Histological examination

Examinations were performed in a Leitz DM-RBE® microscope (Leica, Wetzlar, Germany).

The following linear measurements were made.

- The distance (M-B) between the implant margin (M) and the most coronal level of bone-to-implant contact (B).
- The degree of bone-to-implant contact (BIC percentage), both in the defect region and in the apical region of the implant. The assessment in the defect region was made from level B to a position 5 mm apical to M.

A point counting procedure was used to determine the composition of the tissue in the 'defect' region of all test and control sites. A lattice comprising 100 light points (Schroeder & Münzel-Pedrazzoli 1973) was superimposed over the tissue at a magnifi-

cation of $\times 200$ and the percentage area occupied by lamellar bone, woven bone, and bone marrow was determined.

Results

All surgical sites healed uneventfully and, at the time of biopsy, all implant sites were fully submerged. There were no clinical signs of inflammation in the mucosa in the experimental region.

Histological observations

Control site

The bone tissue surrounding a control implant after 4 months of healing is illustrated in Fig. 5. In the marginal 4–5 mm, the implant was surrounded by a wide and dense layer of cortical bone, mainly lamellar bone (Fig. 5a). In the apical portion, only a delicate layer of newly formed bone seemed to be in direct contact with the implant surface (Fig. 5b). This bone tissue was generally less than 0.1 mm wide in the non-threaded regions of the implant, while wider projections of mineralized bone extended from the threads a varying distance into the bone marrow.

The marginal bone-to-implant contact was present close to the abutment–fixture junction (M-B = 0.44 ± 0.48 mm; Table 1). The tissue next to the implant in the mar-

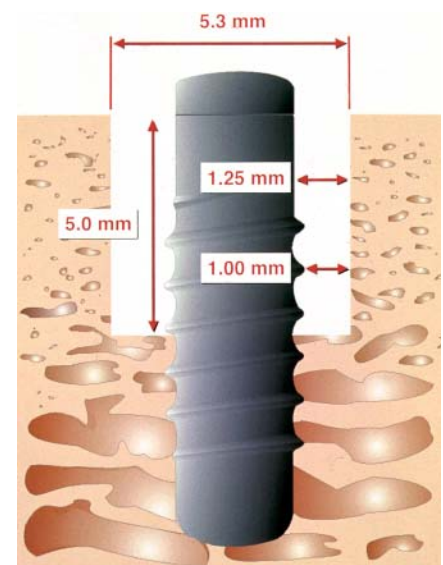


Fig. 4. Schematic drawing illustrating the dimensions of the test site. The defect was 5.3 mm wide and 5 mm deep. The distance between the implant and the bone walls varied between 1 and 1.25 mm.

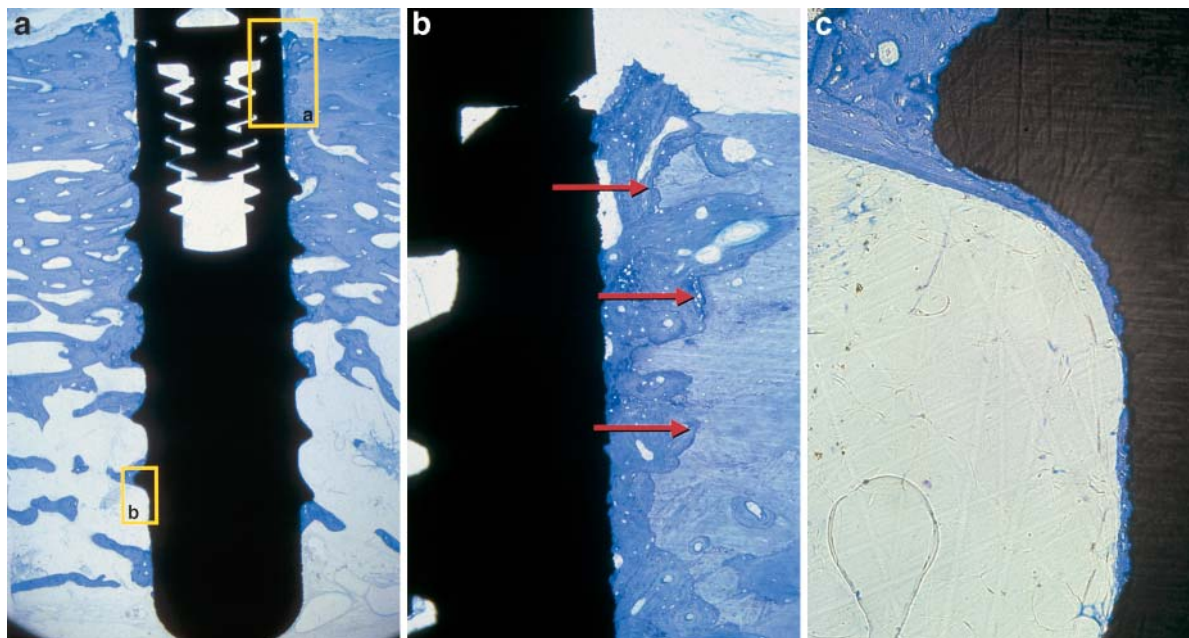


Fig. 5. (a) Ground section (mesio-distal plane) of one control site after 4 months of healing (magnification $\times 16$). Note the dense layer of mainly lamellar bone that occupies the marginal portion of the implant site. The BIC percentage is high. (b) Higher magnification ($\times 100$) of the area included in the marginal frame of the section shown in (a). Note the presence of newly formed bone in direct contact with the SLA surface. The arrows indicate reversal lines between newly formed bone and the older bone tissue. (c) Higher magnification ($\times 200$) of the apical framed area in the section shown in (a). A continuous and delicate layer of newly formed bone appeared to be in direct contact with the SLA surface of the implant.

ginal region was apparently comprised of newly formed bone which could easily be distinguished from the more laterally located older bone. In the 0.3–0.5 mm wide region of newly formed bone, dark blue reversal lines could be seen which separated this tissue from the old bone.

The bone-to-implant contact (BIC percentage; Table 1) in the ‘defect’ region of the implant was $74.1 \pm 4.2\%$. The corresponding value in the apical 5 mm was $73.5 \pm 7.4\%$ (Table 1).

Further, the newly formed tissue appeared to contain a mixture of lamellar and woven bone (lamellar bone = $71.0 \pm 6.7\%$, woven bone = $7.7 \pm 2.7\%$; Table 2).

Test site with barrier membrane

The bone tissue formed during the 4 months of healing appeared to have properly filled the surgically prepared marginal defect (Fig. 6). The marginal level of bone-to-implant contact was observed close to the abutment–fixture junction (M-B =

0.50 ± 0.35 mm; Table 1). The amount of bone-to-implant contact in the marginal ‘defect’ region was large (BIC percentage = $70.3 \pm 4.8\%$; Table 1). The corresponding value for the apical 5 mm was $68.7 \pm 6.1\%$ (Table 1).

The bone tissue in the defect region was comprised of a mixture of lamellar bone and woven bone. In comparison with the control site, the bone in the marginal ‘defect’ region of this test site contained much less lamellar bone ($54.0 \pm 3.8\%$ vs. $71.0 \pm 6.7\%$; Table 2) and more woven bone ($19.2 \pm 3.3\%$ vs. $7.7\% \pm 2.7\%$; Table 2).

Table 1. Results of histometric measurements

	Control	Test	
		Bio-Gide	No membrane
M-B (mm)	0.44 (0.48)	0.50 (0.35)	0.93 (0.84)
BIC (%) within the defect region	74.1 (4.2)	70.3 (4.8)	75.6 (2.7)
BIC (%) for apical 5 mm	73.5 (7.4)	68.7 (6.1)	71.5 (8.4)

Mean values and standard deviations (SD) are shown.

Table 2. Results from morphometric measurements performed within the defect area

	Control	Test	
		Bio-Gide	No membrane
Lamellar bone (%)	71.0 (6.7)	54.0 (3.8)	54.2 (11.2)
Woven bone (%)	7.7 (2.7)	19.2 (3.3)	22.0 (4.9)
Bone marrow (%)	21.3 (4.1)	26.9 (4.2)	23.7 (16.1)

Mean values and standard deviations (SD) are shown.

Test site without barrier membrane

In the sites where the defect following surgery was not protected with a barrier membrane, the bone that had formed during a 4-month period of healing also seemed to have filled the void in the marginal portion of the implant site (Fig. 7). The mean value describing the distance between the abutment–fixture junction and the marginal level of the bone-to-implant contact was 0.93 ± 0.84 mm (Table 1).

The bone-to-implant contact in the ‘defect’ region was $75.6 \pm 2.7\%$ and the corresponding value in the apical region was $71.5 \pm 8.4\%$ (Table 1).

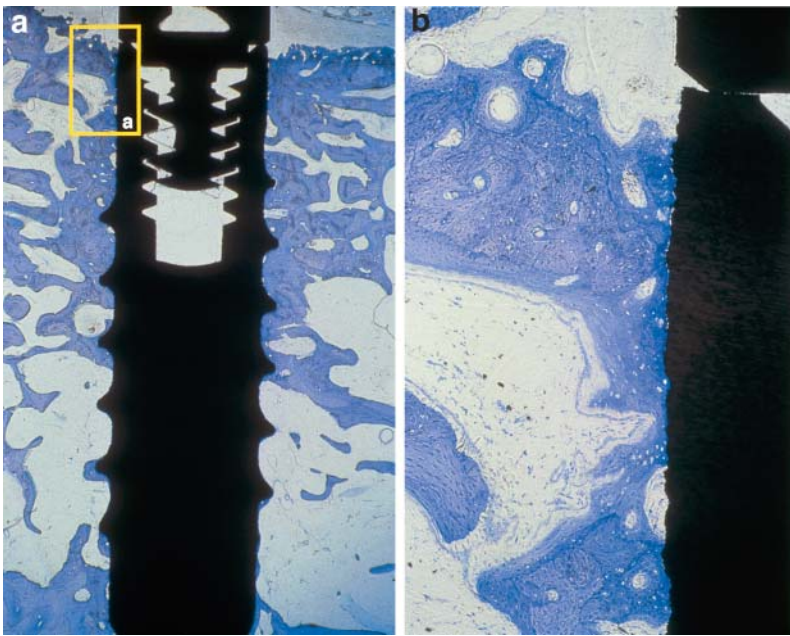


Fig. 6. (a) Ground section (mesio-distal plane) of one test site after 4 months of healing (magnification $\times 16$). During surgery a barrier membrane was used to protect the defect. After 4 months of healing the newly formed bone appeared to have properly filled the marginal defect. (b) Higher magnification ($\times 100$) of the framed area in the section shown in (a). A high degree of bone-to-implant contact was established.

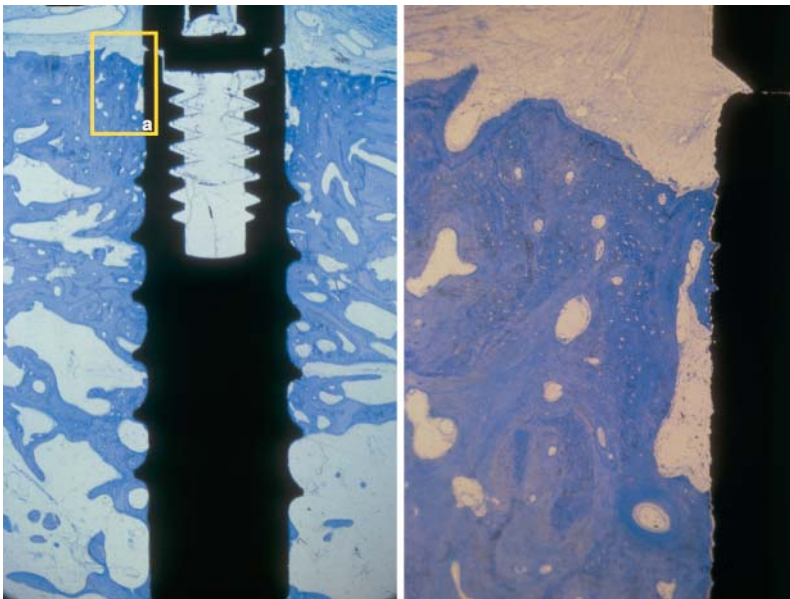


Fig. 7. (a) Ground section (mesio-distal plane) of one test site after 4 months of healing (magnification $\times 16$). No barrier membrane was used to protect the defect in this particular site. After 4 months of healing the marginal defect had been completely filled with new bone. (b) Higher magnification ($\times 100$) of the framed area of the section shown in (a).

The newly formed bone tissue was comprised of $54.2 \pm 11.2\%$ lamellar bone, $22.0 \pm 4.9\%$ woven bone and $23.7 \pm 16.1\%$ bone marrow (Table 2).

Discussion

The findings of the present experiment revealed that a large marginal defect, present

at the time of implant installation, after 4 months of healing had been filled with newly formed bone. In addition, the degree of bone-to-implant contact between the newly formed tissue and the SLA surface was at all test sites high and similar to that obtained at control sites with no defect present at installation. Further, in the current model the placement of a barrier membrane following implant installation did not improve the outcome of healing.

Bone formation in the defect

The finding that a wide circumferential defect, present in the marginal aspect of the implant following installation, after 4 months of healing was more or less entirely filled with new bone is in agreement with findings reported by Persson et al. (1999) and Wetzel et al. (1999). In those studies, ligature-induced peri-implantitis, including the formation of wide (> 2 mm) and deep (> 3 mm) crater-like defects, was first induced. The diseased sites were subsequently treated according to a regimen that included mechanical debridement of the implant surface, curettage of the defect and administration of systemic antibiotics to eliminate the infection. The findings from the experiments revealed that this treatment allowed the formation of large amounts of new bone in the previous defect sites. In this context it must be recognized, however, that in the experiment by Wetzel et al. (1999) substantial bone fill only occurred at defect sites which were protected during healing by a barrier membrane. In the current study, similar amounts of new bone formed in barrier-protected and non-protected sites.

The observation that proper bone fill can occur in a defect that at the time of implant installation was > 1 mm wide is not, however, in agreement with findings previously obtained from experiments in different animal models, e.g. Carlsson et al. (1988), Caudill & Meffert (1991), Knox et al. (1991) and Akimoto et al. (1999). In the above studies it was concluded that, dependent on the implant surface characteristics, bone healing became incomplete if a gap 0.5–1 mm wide occurred between the implant and the bone walls following installation. One important difference between the studies referred to and the current experiment is the time allowed for healing following implant installation. In the present study, healing was evaluated

after 4 months, while in the other experiments shorter healing intervals were used (from 8 to 12 weeks).

Osseointegration

New bone formation in the test sites resulted not only in the elimination of the gap but also in the establishment of a high degree of bone-to-implant contact or osseointegration. Indeed, the amount of mineralized bone (Table 1) found to be in contact with the SLA surface in the test sites (70.3–75.6%) was similar to that found in the control sites (74.1%). While the amount of osseointegration did not differ between the test and control sites, the quality of the bone that filled the defect area in the two sites was markedly different. Thus, in the control sites 71.0% of the bone was of lamellar type and only 7.7% was immature bone, but in the test sites the proportion of woven bone was much higher, i.e. 19.2–22.0%. There is evidence to suggest, however, that this immature bone over time may remodel into lamellar bone (Schenk et al. 1994).

In the present study, implants designed with a SLA, i.e. rough, surface were used. There is evidence to suggest that the use of implants with such a surface may influence the amount of new bone and the amount of new bone-to-implant contact achieved during healing. In a recent study by Persson et al. (2001b), experimental peri-implantitis was induced around implants with either a turned or a SLA surface. In all experimental sites, healing following treatment resulted in marked bone fill in the marginal craters. However, while substantial amounts of re-osseointegration (83.7%) occurred at SLA implants, the amount of bone-to-implant contact at the turned implants was only 21.8% of the original defect depth.

Influence of barrier membrane

In each quadrant, two experimental sites were protected with a barrier membrane following surgery while one site was left without membrane. It was observed that, after 4 months of healing, the amount of bone and the quality of the newly formed bone were similar in the membrane-protected and non-protected sites. Clearly, the

preparation of the implant bed during surgery resulted in a circular defect within the bone tissue. This defect obviously allowed the formation of a coagulum that, even in the absence of a barrier membrane, was properly protected by the periosteum of the soft tissue flap. In other words, during healing of a 'self-contained' bone defect and in the presence of a proper periosteum, the use of a barrier membrane may not be required. At sites, however, where the bone defect has a design that does not promote the retention of the coagulum and the granulation tissue, a barrier membrane fulfils an important role as a space-keeping device (Schenk et al. 1994).

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Résumé

Après l'avulsion dentaire, une alvéole présente souvent une dimension considérablement plus grande que le diamètre d'un implant conventionnel. La guérison qui se déroule à côté des implants placés dans des sites avec une lésion marginale large a été étudiée. Quatre labradors ont été utilisés pour cette étude. Du côté droit de la mandibule quatre sites expérimentaux ont été préparés pour recevoir des implants en titane avec surface SLA. L'installation traditionnelle de l'implant (contrôle) a été effectuée dans un site. Dans les trois derniers (tests), un foret a été utilisé pour élargir 5 mm de la partie marginale du canal. A la suite du placement dans le site test, un espace circonferentiel de 1–1,25 mm de large et de 5 mm de profondeur était présent autour de l'implant. Une membrane barrière résorbable a été placée pour recouvrir l'implant et du tissu osseux de deux sites tandis qu'un site restait non-recouvert. Quatre mois après l'installation de l'implant, des biopsies en bloc de chaque implant ont été obtenues et préparées pour des coupes. Après quatre mois de guérison, la lésion marginale large a été résorbée par de l'os néoformé. Le degré de contact os-implant entre le tissu néoformé et la surface SLA était au niveau de tous les sites tests important et semblable à celui obtenu au niveau des sites contrôles. Le placement d'une membrane barrière après l'insertion de l'implant n'améliorait pas l'état de cette guérison. Une lésion marginale de largeur >1mm peut guérir avec du nouvel os et un haut degré d'ostéointégration au niveau d'un implant avec une surface SLA.

Zusammenfassung

Hintergrund: Nach Zahnextraktion ist die Dimension der Alveole oft grösser als der Durchmesser eines konventionellen Implantats.

Ziel: Das vorliegende Experiment wurde durchgeführt, um die Heilung bei Implantaten, welche in Empfängerstellen mit breiten marginalen Defekten eingesetzt werden, zu untersuchen.

Material and Methoden: Es wurden vier Labradorhunde verwendet. Auf der rechten Seite im Unterkiefer wurden 4 experimentelle Stellen zur Aufnahme von Titanimplantaten präpariert (SLA Oberfläche). An einer Stelle erfolgte eine konventionelle Implantation (Kontrolle). Bei den übrigen 3 Stellen (Test) wurde ein Stufenbohrer verwendet, um die marginalen 5mm des Kanals zu erweitern. Nach dem Setzen der Implantate in die Teststellen bestand eine Lücke mit einer Breite von 1–1.25mm und einer Tiefe von 5mm rund um die Implantate. Bei 2 Stellen wurde eine resorbierbare Membran eingesetzt, um die Implantate und das Knochengewebe abzudecken, während eine Stelle unbedeckt blieb. Vier Monate nach der Implantation wurden von jeder Implantatstelle Blockbiopsien gewonnen und für Schlißpräparate aufgearbeitet.

Resultate: Nach einer Heilungszeit von 4 Monaten hatten sich die grossen marginalen Defekte mit neugebildetem Knochen aufgefüllt. Das Ausmass des Knochen-Implantat-Kontakts zwischen dem neugebildeten Gewebe und den SLA-Oberflächen war an allen Teststellen hoch und den Kontrollstellen sehr ähnlich. Die Platzierung einer Barrieremembran nach Implantation verbesserte das Heilungsergebnis nicht.

Schlussfolgerung: Ein marginaler Defekt breiter als 1mm kann bei einem Implantat mit SLA-Oberfläche mit neuem Knochen und einem hohen Grad an Osseointegration ausheilen.

Resumen

Antecedentes: Tras la extracción de dientes el alveolo presenta con frecuencia una dimensión que puede ser considerablemente mayor en diámetro que un implante convencional.

Objetivo: El presente experimento se llevó a cabo para estudiar la cicatrización adyacente a implantes en lugares receptores con un defecto marginal ancho.

Material y métodos: Se usaron cuatro perros labrador. En el lado derecho de la mandíbula se prepararon 4 lugares experimentales para recibir implantes de titanio (superficie SLA). En 1 lugar se llevó a cabo una instalación tradicional de implante (Control). En los 3 lugares restantes (Prueba), se usó una fresa para ensanchar el margen 5 mm del canal. Tras la colocación del implante en el lugar de prueba, se encontraba presente una dehiscencia circunferencial, lateralmente al implante, de alrededor de 1–1.25 mm de ancho y 5 de profundidad. Se colocó una membrana de barrera para cubrir el implante y el tejido óseo de 2 lugares mientras que 1 lugar se dejó sin cubrir. Tras 4 meses de la instalación del implante se obtuvieron biopsias en bloque de cada implante y se prepararon para ser seccionadas.

Resultados: Tras 4 meses de cicatrización el defecto marginal se había rellenado con hueso neoformado. El grado de contacto hueso-implante entre el tejido neoformado y la superficie SLA fue similar en todos los lugares de prueba al que se obtuvo en los lugares de control. La colocación de una membrana de barrera tras la instalación del implante no mejoró los resultados de la cicatrización.

Conclusión: Un defecto marginal mayor de 1 mm puede cicatrizar con hueso neoformado y alto grado de osteointegración a un implante diseñado con una superficie SLA.

要旨

背景：抜歯後に抜歯窩は従来のインプラントの直径よりかなり大きい寸法となる場合が多い。

目的：本実験は広い辺縁骨欠損部に埋入したインプラントに隣接する部位で起こる治癒を検討するために行った。

材料と方法：4匹のラブラドル犬を用いた。下顎右側に4箇所チタン製インプラント（SLA表面）の骨床を実験的に形成した。伝統的なインプラント埋入（対照部位）を1箇所で行い、残りの

3箇所（試験部位）では、ステップ・ドリルを用いて下顎骨の辺縁5mmを広げた。インプラント埋入後に試験部位では、幅1～1.25mm、深さ5mmの空隙をインプラント全周外側に空隙が存在していた。2箇所では吸収性バリアー・メンブレンを入れ、インプラントと骨組織を被覆したが、1箇所は被覆しないままにした。インプラント埋入4ヵ月後、各インプラント部位のブロック生検を取り、研磨切片を作製した。

結果：治癒4ヵ月後に大きな辺縁骨欠損は新生骨

で埋まっていた。全ての試験部位で新生骨とSLA表面間の骨-インプラントの接触の度合いは高く、対照部位と類似していた。インプラント埋入後のバリアー・メンブレンの使用は治癒の結果を促進しなかった。

結論：SLA表面を有するインプラントにおいて、幅1mm以上の辺縁骨欠損が治癒して、新生骨ができ、高度の骨性統合が達成される可能性がある。

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