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Osseotite® vs. machined surface in poor bone quality

A study in dogs

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Implant sites with low bone content have exhibited lower implant survival rates than dense bone areas. Alterations of the implant surface seem to influence the bone-to-implant contact rate and may have an impact on implant failure rates in such sites. It was the objective of this animal study to histomorphometrically compare two different implant surfaces in so-called poor bone quality sites. All premolars on one side of the mandible were extracted in five fox hounds. After a healing time of 8 months, four screw-type implants (two with a machined surface (ICE group) and two with a double acid-etched (Osseotite®) surface (OSS group)) were inserted into the mandible. Upon insertion, the implant apex was located in the 'hollow' part of the dog mandible, where the bone content is low. After 4 months healing, histomorphometric evaluations were performed. All implants osseointegrated clinically and histologically. Periapical density measurements revealed similar bone contents in both groups (ICE 49.9±16.7%, OSS 52.2±8.4%; $P>0.05$). Despite these similar amounts of bone content in the apical area around the implant, the Osseotite® implant surface had a significantly higher bone-to-implant contact rate than the machined surface (OSS 62.9±12.4%, ICE 39.5±13.0%; $P<0.01$). It is concluded from this animal experiment that, in poor bone quality sites, an implant with an Osseotite® surface can achieve a significantly higher bone-to-implant contact compared to a machined surface.

Implant sites with so-called poor bone quality have been associated with lower implant success rates (Friberg et al. 1991; Jaffin & Berman 1991; Truhlar et al. 1994; Jemt & Lekholm 1995). This clinical observation has been presumed to reflect a lower bone content and a lower bone-to-implant contact (BIC) rate due to the highly cancellous structure of these sites (Devlin et al. 1998; Trisi et al. 1999). Clinical recommendations for such areas were to allow for longer healing periods (Adell et al. 1985) so as not to further compromise the long-term implant success rates.

Since most of these observations have been made in implants with machined surfaces, questions were raised as to whether alterations in implant surface morphology would increase the BIC in general, and thus clinical success rates, too. Histological studies in animals and humans were indeed able to demonstrate a higher BIC in implants with a roughened surface compared to a machined surface (Buser et al. 1991; Weinländer et al. 1992; Gotfredsen et al. 1995; Wennerberg et al. 1995; Gottlander et al. 1997; Lazzara et al. 1999; Cordioli et al. 2000; Ivanoff et al. 2001). Moreover, short-term success rates with rough surface implants seem to be higher in areas with low bone content compared to machined-surface implants (Drago 1992; Olsson et al. 1995; Friberg et al. 1997; Sullivan et al. 1997; Cochran 1999; Davarpanah et al. 2001; Testori et al. 2001).

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It was the aim of this study in the dog mandible to further compare BIC rates of two different implant surfaces (machined vs. Osseotite®) in sites with a low preexisting bone content.

Material and methods

This study was approved by the Animal Welfare Committee of the University of Texas at Houston, Health Science Center and conducted according to the guidelines of the Animal Welfare Act and the Public Health Service Guide for the Care and Use of Laboratory Animals.

General anesthesia in the dogs was induced by pentothal i.v. (15–17 mg/kg) and maintained by gas intubation with 1.5–2 vol% isoflurane. A local injection of lidocaine 2% with epinephrine 1 : 50,000 into the surgical areas was used to reduce intrasurgical hemorrhage. Postsurgically the anesthetic agents ibuprofen p.o. (10 mg/kg) and buprenorphine s.c. (0.01–0.02 mg/kg) were administered.

In five adult female foxhound dogs, all premolars (P1–P4) on one side of the mandible were carefully extracted. This was accomplished after bucco-lingual sectioning the crowns and roots of P2, P3 and P4. After a healing period of 8 months, a crestal incision was made in the edentulous area, and buccal and lingual mucoperiosteal flaps were raised. Osteotomies were performed according to the implant manufacturer's guidelines. Two machined screw-type titanium implants (ICE, Implant Innovations, Inc., Palm Beach Gardens, FL, USA; ICE group) and two double acid-etched screw-type titanium implants (Osseotite®, Implant Innovations, Inc., Palm Beach Gardens, FL, USA; OSS group) with a diameter of 3.75 mm and a length of 10 mm were inserted. Same surfaced implants were positioned next to each other, and located alternatively either in the mesial or the distal half of the edentulous area. Cover screws were installed on top of the implants (Fig. 1), and the flaps were closed with horizontal mattress and interrupted sutures (Gore-Tex® Suture CV-6, W.L. Gore & Associates, Flagstaff, AZ, USA) to submerge the implants completely. Until suture removal after 10 days, the surgical sites were sprayed with chlorhexidine digluconate 0.2% five times a week, and thereafter three times a week until the end of the experiment.

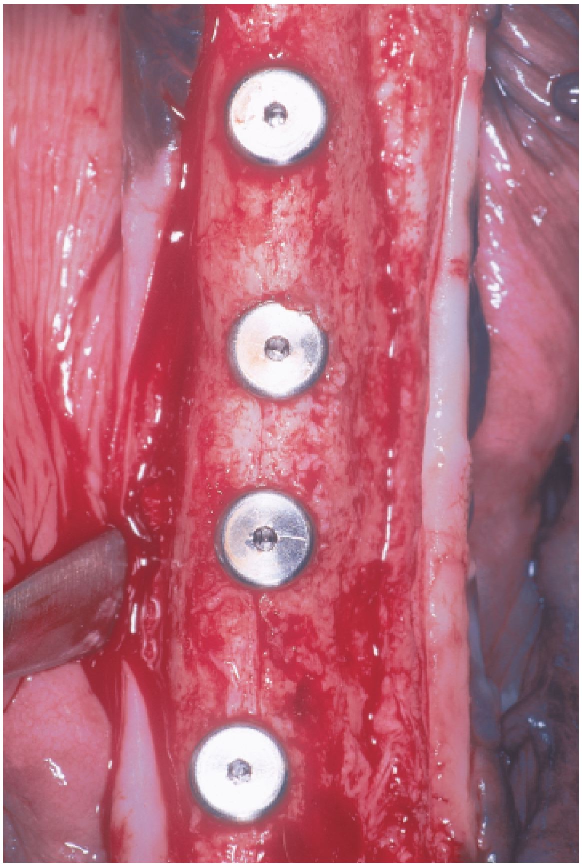

Fig. 1. Four screw-type implants (two with machined surface and two with double acid-etched surface) were inserted into the edentulous area. Implants with the same surface were placed next to each other.

Following a healing period of 4 months, the animals were sacrificed by exsanguination. After a carotid artery cut-down procedure, the heads of the animals were perfused with 10% neutrally buffered formalin. The block-resected, implant-containing parts of the mandible were embedded in light-cured composite material (Technovit 7200 VLC®, Kulzer & Co. GmbH, Friedrichsdorf, Germany), and two to three sections of the center of the implant were cut in the bucco-lingual direction and ground to a thickness of 30 μm according to the method of Donath & Breuner (1982). Subsequently, the sections were stained with toluidine blue solution.

The histologic and histomorphometric evaluation was performed with the aid of a light microscope equipped with a video-TV camera and coupled to a personal computer. The computer program Image-Pro Plus (Media Cybernetics, Inc., Del Mar, CA, USA) was used to perform the analysis.

The following parameters were assessed:

1. *BIC rate in an area of low bone content*: The apical part of the implant, i.e. the part of the implant that was located in the hollow part of the mandible, was traced to determine its total length. Tracing was started on one side of the implant at the point where the vent structure started to become visible. It was continued in an apical direction around the implant apex and ended at the same height level as on the opposite side. This corresponded to the apical 3.5 mm of the total implant length of 10 mm. Direct contact between mineralized bone tissue and the implant surface along this distance was expressed as a percentage of the total apical implant length traced.
2. *Bone density in an area of low bone content*: At a lateral distance of 1 mm from the implant surface, two squares of 1 mm² each were placed next to the implant in the host bone (one on the buccal and one on the lingual side). The

apical sides of the squares were level with the apical border of the implant. The area occupied by mineralized bone tissue within these squares was expressed as a percentage of the total square area. The mean of the buccal and lingual square was calculated.

The measurements of each section were averaged to obtain mean values for each of the four implants per dog. Implants with the same surface were further averaged in each dog, which produced two means per dog: one for the smooth surface and one for the rough surface. The dog was chosen as the statistical unit, and the paired Student's *t*-test was used to detect differences between the two treatment groups.

Results

Histological observations

All implants in both the ICE and OSS groups were histologically osseointegrated without any signs of inflammation or connective tissue interposition at the bone–implant interface.

Implant sections of the ICE group showed a high BIC in the areas of high bone content, i.e. in the coronal and intermediate thirds of the implant where the buccal and lingual compact bone plates were engaged. The apical third of the implant was located in the hollow part of the mandible above the nerve and vessel bundles where bone trabeculae were scarce. BIC was infrequent and mostly limited to areas where bone trabeculae were in contact with parts of the implant (Fig. 2).

Implant sections of the OSS group exhibited similar features as the ICE group, with the exception of a more continuous BIC in the apical region of the implant. Even in areas where bone trabeculae were not nearby, BIC was frequently observed (Fig. 3). A continuous line of newly formed bone was often noted surrounding major parts of the implant apex. Such continuous linings with new bone were also visible in invaginated areas of the implant such as the vent (Fig. 4).

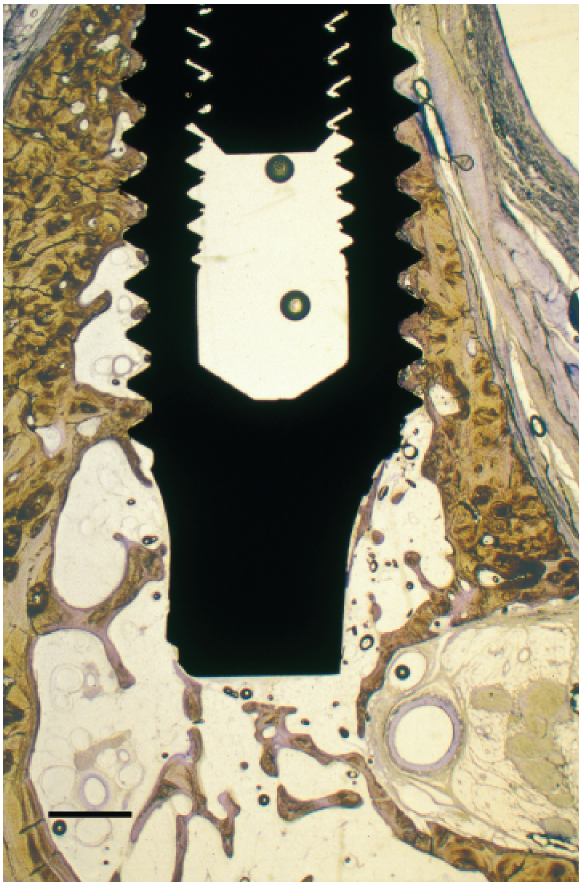

Fig. 2. Overview section of an implant of the ICE group. The BIC is high where the implant engages the buccal and lingual bone plates whereas the BIC around the implant apex is more infrequent and limited to areas where bone trabeculae contact the implant. Toluidine blue. Bar equals 1 mm.

Histomorphometrical measurements

The results of the BIC rates and bone density measurements can be seen in Table 1. The percentage of bone in the area around the implant apex was approximately 50% with no significant differences between the two groups ($P = 0.78$). There was a difference of 23% in BIC rates between the ICE and OSS groups, which corresponds to an increase by more than 50% in the OSS group compared to the ICE group ($P<0.01$).

Discussion

The results of this animal study demonstrate a significantly higher BIC rate in areas of low bone content if implants with an Osseotite® surface are used compared to machined-surface implants.

The fact that implants with an acid-etched surface have a high BIC rate has long been known. Buser et al. (1991) have shown that, after 3 and 6 weeks of healing in the miniature pig, the BIC rate was significantly better in implants with a sandblasted and acid-etched surface compared to a smooth (electropolished) implant surface. Later studies confirmed this observation for implants with a double acid-etched surface (Cordioli et al. 2000). However, it was not until recently that the attention of surface research started focussing on areas where long-term success rates of implants have been lower. Lazzara et al. (1999) were able to demonstrate histomorphometrically a significantly higher BIC rate after 6 months in the posterior maxilla of humans when a double acid-etched surface (73% BIC rate) was used as opposed to a machined surface (34%). Their results compare favorably with our results. However, it has to be mentioned that due to the low number of animals ($n = 5$) in our study, interpretations of the results should be made carefully.

In general, implants seem to have lower survival rates in areas with low bone content as compared to areas with dense

Fig. 3. Overview section of an implant of the OSS group. The BIC is high all around the implant and shows a continuous BIC even in the apical area. Toluidine blue. Bar equals 1 mm.

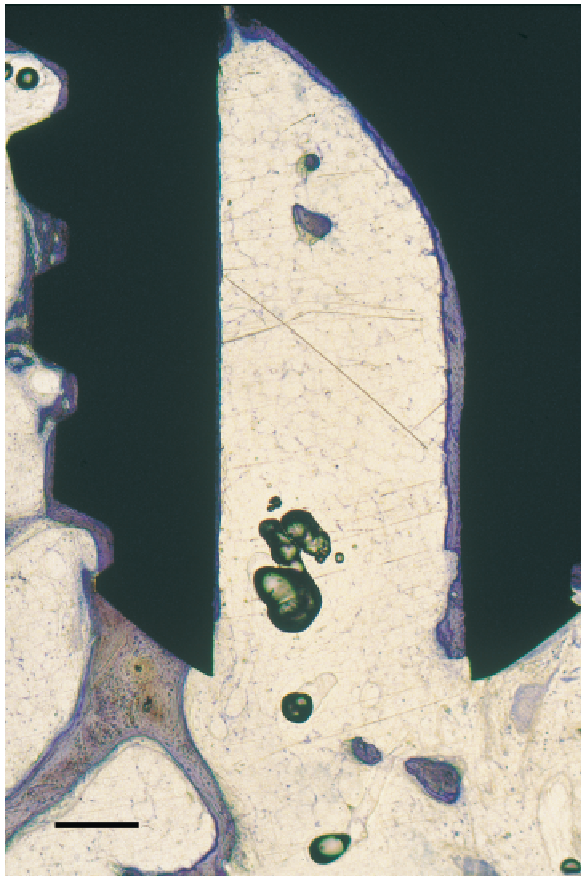

Fig. 4. Magnification of an implant of the OSS group. Note the continuous line of newly formed bone extending into the vent area. Toluidine blue. Bar equals 0.3 mm.

***Table 1.* Histomorphometric comparison between ICE and OSS group (n = number of animals)**

Groups	n	Bone density		BIC rate	
		mean±SD	P	mean±SD	P
ICE	5	49.9±16.7%		39.5±13.0%	
OSS	5	52.2±8.4%	0.78	62.9±12.4%	<0.01

bone (Olsson et al. 1995; Friberg et al. 1997; Cochran 1999). This has been accounted for by the spongy bone structure, which results in a lower BIC rate than compact bone. The percentage of bone in areas such as the posterior maxilla has been determined in the literature to be around 20% (Ulm et al. 1999). The values for bone density in our study were 49.9% and 52.2%, respectively. These values seem to be relatively high for a site of low bone content and can be explained by the fact that our assessment squares for bone density were located buccally and lingually of the implant apex. A strictly apical location of the square, i.e. apical of the implant apex, would have produced lower bone densities but would not have taken into account that the buccal and lingual surfaces of the apical third of the implant were sometimes in the neighborhood of the buccal and lingual compact bone plates. This proximity was caused by a not strictly parallel inclination of the outer shape of the mandible in relation to the implant length axis. Since the assessment of the BIC rate in the apical third of the implant included three sides (buccal, apical, lingual), the reported location of the assessment squares seemed to be more appropriate. The obviously lower bone density apical of the implant apex is also confirmed by the fact that the BIC rate along the very apical border of the implant dropped down to only 20.3±13.9% in the ICE group and stayed nearly the same with 60.6±12.6% in the OSS group (P = 0.01).

Apart from accelerating the time periods needed for osseointegration, a change of implant surface design can have only one purpose: to further improve long-term survival rates of implants. Although almost all implant manufacturers have more or less banned machined-surface implants from their shelves, only few can provide scientific proof that altering their implant surface actually improves their survival rates, especially in sites of low bone content (Sullivan et al. 1997; Grunder et al. 1999; Davarpanah et al. 2001; Sullivan et al. 2001; Testori et al. 2001). Long-term reports regarding this issue are lacking completely.

In conclusion, this animal study provided further support for the superior ability of the Osseotite® surface to produce higher BIC rates than a machined implant surface.

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Résumé

Les sites implantaires au contenu osseux faible sont associés à des taux de survie implantaire inférieurs aux zones ayant un contenu d'os dense. Des altérations de la surface implantaire semblent influencerle taux de contact os-implant et pourraient avoir un impact sur les taux d'échec des implants dans de tels sites. Le but de cette étude a été de comparer hystomorphométriquement deux surfaces implantaires différentes dans des sites aux qualités osseuses pauvres. Toutes les prémolaires d'un côté de la mandibule ont été avulsées chez cinq chiens terriers. Après un temps de guérison de huit mois, quatre implants de type vis [deux usinés (groupe ICE) et deux doublement mordançés (Osséotite®; groupe OSS)] ont été placés dans la mandibule. Après cette insertion, l'apex de l'implant a été localisé dans la partie caverneuse de la mandibule des chiens o le contenu osseux est faible. Après quatre mois de guérison, les évaluations histomorphométriques ont été effectuées. Tous les implants étaient ostéointégrés tant cliniquement qu'histologiquement. Des mesures de la densité périapicales ont révélé des teneurs osseuses semblables dans les deux groupes (ICE 50±17%, OSS 52±8%; P>0,05). Malgré ces quantités semblables en teneur osseuse dans la zone apicale autour des implants, la surface implantaire Osséotite® avait un contact os-implant significativement plus important qu'au niveau de la surface usinée (OSS 63±12%, ICE 40±13%; P<0,01). Chez le chien, dans les sites aux mauvaises qualités osseuses, un implant avec une surface Osséotite® entrane un contact implant-os significativement plus important comparé à celui avec une surface usinée.

Zusammenfassung

Die Osseotite® Oberfläche im Vergleich zur maschinell bearbeiteten Oberfläche bei schlechter Knochenqualität. Eine Studie an Hunden

Implantatstellen mit niedrigem Knochengehalt zeigten tiefere Implantatüberlebensraten als Regionen mit dichtem Knochen. Veränderungen der Implantatoberfläche scheinen die Knochen-Implantat-Kontaktrate zu beeinflussen und könnten einen Einfluss auf die Misserfolgsrate von Implantaten an solchen Stellen haben. Das Ziel dieses Tierexperiments war es, zwei verschiedene Implantatoberflächen an Stellen mit sogenannt schlechter Knochenqualität zu vergleichen. Bei fünf Foxhunden wurden auf einer Seite im Unterkiefer alle Prämolaren extrahiert. Nach einer Abheilzeit von 8 Monaten wurden 4 schraubenförmige Implantate (2 mit maschinell bearbeiteter Oberfläche {ICE Gruppe} und 2 mit doppelt säuregeätzter Osseotite® Oberfläche {OSS Gruppe}) im Unterkiefer eingesetzt. Nach der Platzierung befand sich der Apex der Implantate im Bereich der ''hohlen'' Region des Hundeunterkiefers, wo der Knochengehalt gering ist. Nach einer Heilungszeit von 4 Monaten wurden histomorphometrische Untersuchungen durchgeführt. Alle Implantate waren klinisch und histologisch osseointegriert. Periapikale Dichtemessungen ergaben in beiden Gruppen einen ähnlichen Knochengehalt (ICE 49.9+/−16.7%, OSS 52.2+/−8.4%; P>0.05). Obwohl in den apikalen Regionen der Implantate ein ähnlicher Knochengehalt bestand, zeigten die Osseotite® Implantatoberflächen signifikant mehr Knochen-Implantat-Kontakt als die maschinell bearbeiteten Oberflächen (OSS 62.9+/−12.4%, ICE 39.5+/−13.0%; P<0.01). Aus diesem Tierexperiment wird die Schlussfolgerung gezogen, dass ein Im-plantat mit Osseotite® Oberfläche an Stellen mit schlechter Knochenqualität einen signifikant grösseren Knochen-Implantat-Kontakt erreichen kann als eine maschinell bearbeitete Oberfläche.

Resumen

Los lugares de implantes con un bajo contenido en hueso han mostrado unos índices de supervivencia mas bajos que las áreas de hueso denso. Las alteraciones en la superficie del implante parecen influir en la tasa de contacto hueso implante y pueden tener un impacto en el índice de fracaso de los implantes en dichas áreas. Este fue el objetivo de este estudio animal, comparar histomorfometricamente dos superficies de implantes diferentes en los llamados lugares de baja calidad de hueso. Se extrajeron todos los premolares de un lado de la mandíbula de cinco perros de zorro. Tras cicatrizar durante 8 meses, se insertaron en la mandíbula 4 implantes roscados (2 con superficie pulida (grupo ICE) y 2 con superficie doblemente gravada con ácido (Osseotite®) (grupo OSS). Al insertarse, el ápice del implante se situó en la parte hueca de la mandíbula del perro donde el contenido de hueso es bajo. Tras cuatro meses de cicatrización, se llevaron a cabo evaluaciones histomorfométricas. Todos los implantes se osteointegraron clínica e histológicamente. Las mediciones de la densidad periapical revelaron contenidos similares de hueso en ambos grupos (ICE 49.9±16.7%, OSS 52.2±8.4%; P<0.05). A pesar de estos contenidos similares de cantidad de hueso en el área apical alrededor del implante, la superficie de implante Osseotite® tuvo un contacto hueso implante significativamente mas alto que las superficies pulidas (OSS 62.9±12.4%, ICE 39.5±13.0%; P<0.01). Se concluye de este estudio animal experimental que, en lugares de baja calidad de hueso, un implante con una superficie Osseosite® puede lograr un contacto hueso a implante significativamente mas alto en comparación con una superficie pulida.

要旨：

骨量の少ないインプラント部位は、骨密度が高い部位より、インプラントの生存率が低いことが示されている。インプラント表面の修飾は骨とインプラントの接触率に影響を及ぼすように思われ、前述のような部位のインプラントの失敗率に影響を及ぼす可能性がある。本動物研究の目的は、いわゆる骨質の悪い部位における２つの異なるインプラント表面の性状を組織形態計測学的に比較することであった。５匹のフォックス・ハウンド犬において、下顎片側の前臼歯を全て抜去した。８ヶ月の治癒期間後、４本のスクリュー型インプラント（機械加工表面のもの２本［ICE群］と２重酸エッチング表面（Osseotite®）のもの２本［OSS群］）を下顎に埋入した。インプラントの先端部が、骨量が少ない犬の下顎骨の『中空』部分に位置するように埋入した。４ヶ月の治癒期間後に組織形態計測学的評価を行った。インプラントは全て臨床的にも組織学的にも骨性結合を獲得していた。先端周囲の骨密度測定により、両群の骨量が類似していることが分かった（ＩＣＥ４９．９±１６．７％、ＯＳＳ５２．２±８．４％；ｐ＞０．０５）。インプラント先端周囲の骨量が類似しているにもかかわらず、Osseotite® インプラント表面は機械加工表面よりも、有意に高い骨とインプラントの接触率を示した（OSS６２．９±１２．４％、ICE３９．５±１３．０％；ｐ＜０．０１）。本動物実験の結論として、骨質の悪い部位では、Osseotite® 表面のインプラントは、機械加工表面のものに比べて、優位に高い骨とインプラントの接触率を獲得できる。

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