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Osseointegration of subperiosteal implants using bovine bone substitute and various membranes

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An earlier study revealed incomplete osseointegration of individually made titanium subperiosteal implants covered by ePTFE membranes and fixated to the rabbit tibial bone surface. In addition, the newly-formed bone was dominated by large marrow spaces. In this subsequent study, subperiosteal implants were also fixated on the bone surface of both tibia of 9 Copenhagen White rabbits. Bio-Oss® particles were packed densely covering the entire implant surface. One of 3 different membranes covered the implant and the particles. The membranes used were the degradable Polyglactin 910® mesh, a degradable bilayer collagen membrane and the non-degradable ePTFE membrane. Undecalcified sections were prepared for histologic evaluation after a 12 weeks' observation period. All 18 subperiosteal implants were completely osseointegrated. In addition, the marrow spaces were reduced compared to our previous study. The Bio-Oss® particles proved to be biocompatible and osteoconductive. The ePTFE membranes revealed neither signs of collapse nor adjacent infiltration of inflammatory cells. The Polyglactin 910 mesh and the bilayer collagen membranes collapsed slightly. There were signs of resorption of the surface of the newly-formed bone under the degradable membranes. The cause of resorption can not be documented.

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The prognosis of implant installation in atrophic jaws is generally very good (Albrektsson et al. 1986). However, a certain amount and quality of bone is necessary. Autogenous bone grafts are widely used for augmentation of extremely atrophic jaws, before or simultaneous with implant placement. However, preliminary experimental studies have indicated that the earlier abandoned subperiosteal implants could be of interest (Schmid et al. 1991) in the treatment of extremely atrophic jaws (Hjørting-Hansen et al. 1995; Schmid et al. 1991). Subperiosteal implants covered by ePTFE membranes (Gore-Tex®, W.L. Gore and Associates, Flagstaff, AZ, USA) were used in these studies to prevent undesired cells from invading the tissues surrounding the implant. Complete osseointegration of the subperiosteal implants was noted in the study by Schmid and co-workers (1991), whereas the implants were only partly covered by newly-formed bone in our study (Hjørting-Hansen et al. 1995). In addition, large marrow spaces in the space between the implant and the membrane were noted.

Bone substitutes have been used to improve repair of bone defects (Klinge et al. 1992; Ripamonti 1992; Thaller et al. 1993) and in various augmentation procedures (Block & Kent 1985; Berglundh & Lindhe 1997; Frame 1987; Gotfredsen et al. 1991; Moy et al. 1993; Wetzel et al. 1995; Zitzman et al. 1997). Several experimental and clinical studies have documented the highly biocompatible and osteoconductive characteristics of Bio-Oss® par-

ticles (Geistlich Pharma, Wolhusen, Switzerland) (Klinge et al. 1992; Storgaard-Jensen et al. 1996; Thaller et al. 1993). Consequently, concomitant use of subperiosteal implants and Bio-Oss® covered by a membrane may establish the optimal conditions for osseointegration of subperiosteal implants.

The purpose of the present experiment was therefore to study whether complete osseointegration of individually made titanium subperiosteal implants could be obtained concomitant with prevention of large marrow spaces formation in the newly-formed bone by using a bovine bone substitute and various membrane types.

Material and methods

A license to perform the study was obtained from the Danish National Experimental Animal Inspectorate.

Experimental animals

Nine adult female Copenhagen White rabbits (*Oryctolatus Cuniculus*) with closed epiphyseal plates were used. The animals were kept in single cages and fed a dried standard rabbit diet (Slangerup Foderstofforretning, Slangerup, Denmark) and water ad libitum.

Anesthesia and drug administration

The animals received streptomycin-benzylpenicillin (Streptocillin Vet®, 200,000 i.u./ml, Novo Industries, Denmark, 0.25 ml/kg, i.m.) just before the surgical procedure. General anesthesia was induced by fluanison (Hypnorm®, Janssen Pharmaceutica, Beerse, Belgium, 0.5 ml/kg, i.m.) and diazepam (Stesolid®, Dumex, Copenhagen, Denmark, 0.4 ml/kg, i.m.). The site of surgery was infiltrated preoperatively with 1 ml lidocaine adrenaline (Xylocain® adrenaline, 20 mg/ml + 12.5 µg/ml, Astra, Södertälje, Sweden). Postoperatively, streptomycin-benzylpenicillin (Streptocillin Vet®, 200,000 i.u./ml, Novo Industries, Denmark, 0.125 ml/kg, i.m.) were given for the subsequent 3 days.

Surgical procedure

The hind legs of the rabbits were initially shaved and washed with 0.1% aqueous chlorhexidine digluconate. The medial part of both tibia were exposed via a skin incision and careful subperiosteal dissection. To facilitate later precise implant localization, a sign was made in the bone surface by a burr. An impression of the bone surface was made with Impregum® (ESPE, Seefeld, Germany). The periosteum and muscular layers were repositioned and sutured by non-degradable sutures (Miralene®, Braun Melsungen, Germany). The skin was sutured by degradable sutures (Vicryl®, Ethicon, Noderstedt, Germany). The impressions were used to make individual commercially pure titanium frameworks within 48 h. The thickness of the framework was 0.9 mm. Two central posts with a height of 2 mm were placed to secure space between the membrane and implant and to imitate abutments. A hole was made in both ends for fixation screws. After casting, the framework was acid treated, washed, and sterilized.

Two days after the first operation, the animals were re-anesthetized. Both tibia were exposed through the original incision and the titanium implant was placed unambiguously according to the previously made localization sign with complete congruence with the bone surface. One implant was placed on each tibia. Perforations in the underlying cortex were made with a 1-mm burr according to the fenestrations of the implant (Fig. 1). The space between the posts was packed with a bovine bone substitute soaked in blood (Bio-Oss®, spongiosa, 1–2 mm, Geistlich Pharma, Wolhusen, Switzerland) (Fig. 2). The implant and Bio-Oss® particles were covered at random by an expanded polytetrafluoroethylene (ePTFE) augmentation membrane (Gore-Tex®, Gore, Flagstaff, AZ, USA), a degradable Polyglactin 910 Mesh (Vicryl®, Ethicon, Norderstedt, Germany) (PG), or a degradable bilayer collagen membrane (Bio-Gide®, Geistlich, Wolhusen, Switzerland) (BC). There were 6 observations for each membrane, 18 in total. The size of the membrane was adjusted to cover the implant extending 5 mm beyond the implant edges. The implant and membrane were fixed with two 5-mm screws (W. Lorens Micro System, Martin Medizin-Technik, Tuttlingen, Ger-

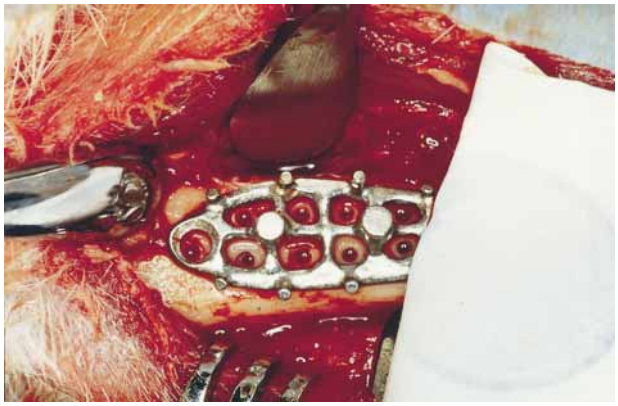

Fig. 1. An individually made commercially pure titanium subperiosteal implant placed on the bone surface. The cortical bone is perforated through the fenestrations of the implant.

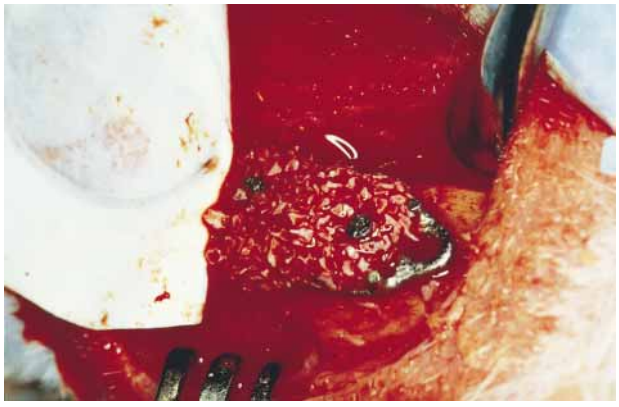

Fig. 2. Implant covered by Bio-Oss® particles soaked in blood. This implant is due to be covered by an ePTFE membrane.

many). The periosteum, muscular layer, and skin were repositioned and sutured as previously described. A similar procedure was performed at the contralateral tibia.

No control group, covering an implant with a membrane but no Bio Oss® particles, was included due to the results obtained in our earlier study (Hjørting-Hansen et al. 1995). The result of the former study was incomplete osseointegration of subperiosteal implants covered by ePTFE membranes and no integration of implants not covered by a ePTFE membrane.

Tissue processing

The animals were sacrificed after 12 weeks with an overdose of pentobarbital (Mebumal®, University Hospital (Rigshospitalet), Denmark). Both tibia were resected 5 mm mesially and distally from the ends of the implant and fixated in 4% neutral buffered formaldehyde for 4 weeks after the bone marrow was exposed by removing the lateral cortical bone and dividing the implant into 2 parts facilitating fixation, dehydration, and embedding in methacrylate. At least 3 to 4 ground sections with a thickness of 25–30 μm were prepared from each implant parallel with the long axis of the tibia. All sections were stained by basic Fuchsin and light green (Gotfredsen et al. 1989).

Results

The postoperative period of the 9 animals was uneventful.

Histology

Expanded polytetrafluoroethylene membrane covered implants. All subperiosteal implants were completely osseointegrated in woven bone (Fig. 3). Furthermore, the majority of Bio-Oss® particles were also integrated in woven bone (Fig. 4). The remaining particles were integrated in marrow spaces and covered by osteoid and osteoblast seams. The surface of the woven bone surrounding implants and particles were covered by osteoid and irregular osteoblast seams. The woven bone was in some areas replaced by parallel fibered bone without a clear pattern. However, resorption of the woven bone could be noted on one side and apposition of bone on the other side in other areas. At the level of the posts, marrow spaces were noted. The hematopoietically active marrow consisted of a large number of blood-forming cells and some fat cells. Numerous vessels were seen in the newly-formed bone.

Some of the surgically created perforations of the cortical bone were occupied by Bio-Oss® particles, hematopoietic tissue in contact with the marrow of the tibia, or minor amounts of woven bone (Fig. 5).

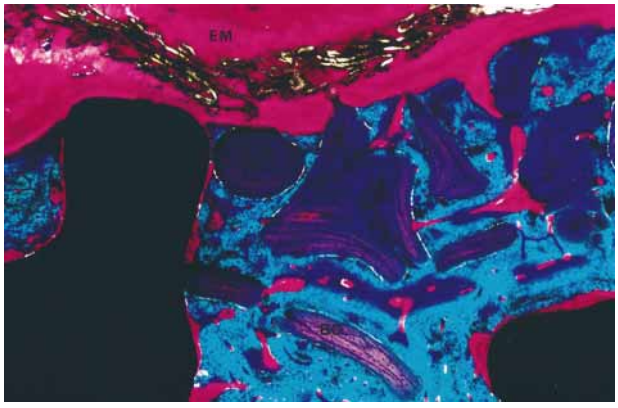

Fig. 3. Osseointegration of a subperiosteal titanium implant covered by Bio-Oss® particles (BO) and an ePTFE membrane (EM). Original magnification ×23.

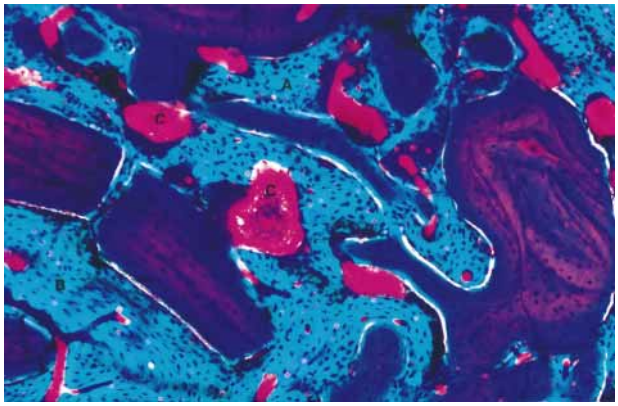

Fig. 4. Bio-Oss® particles surrounded by woven bone. Area A shows woven bone, area B shows parallel fibered bone. Cutting cones (C) are noted. Original magnification ×58.

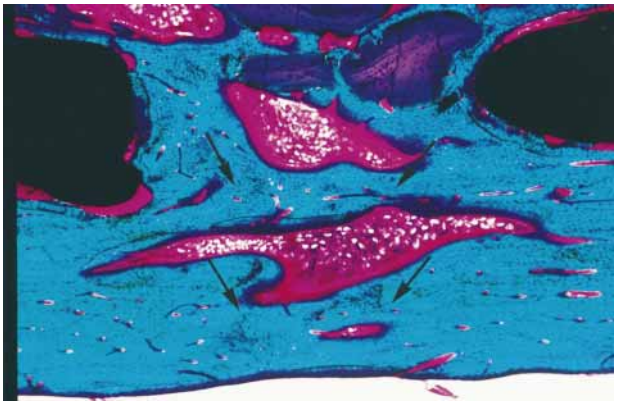

Fig. 5. A former surgically created perforation (arrows) with a mixture of woven bone and hematopoietic tissue. The perforation provided communication between the marrow of the tibia and the experimental area. Original magnification ×23.

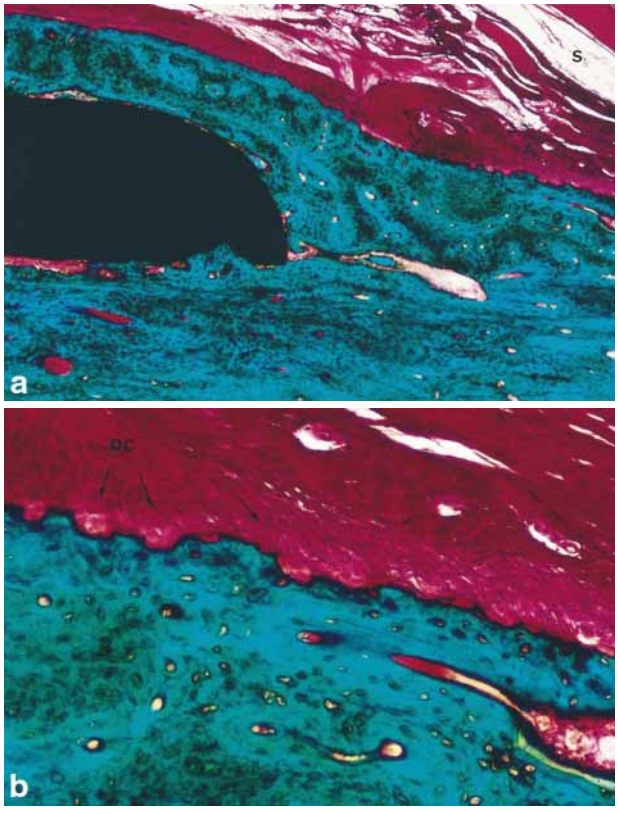

Fig. 6. (a) Osseointegration of a subperiosteal implant covered by Bio-Oss® and a Polyglactin 910 membrane. The space (S) formerly occupied by the membrane can be noted. Original magnification ×30. (b) Higher magnification of area A in Fig 6a. The newly-formed bone under the degraded membrane shows an irregular pattern. The same picture could be noted under degraded bilayer collagen membranes. Osteoclasts can be noted (OC). Original magnification ×115.

Osteoclasts or resorption processes could not be identified on the surface of Bio-Oss® particles. Furthermore, no inflammatory cells were identified adjacent to the particles. However, cutting cones could be noted at the surfaces and in the center of the particles. These cones were filled with woven bone or osteoid and osteoblasts (Fig. 4).

The ePTFE membranes were *in situ* in all the specimens. There were no signs of collapse of the membranes. In addition, all membranes were covered by a thin layer of connective tissue on both surfaces without infiltration of inflammatory cells. Actually bone formation was noted in 2 of the 6 specimens on the outer surface of the membrane.

Polyglactin 910 and collagen membrane covered implants. The histologic characteristics of implants covered by PG or BC membranes were rather similar. Consequently, they will be described simultaneously.

All implants were osseointegrated in woven bone (Fig. 6a). However, the implant posts were not fully integrated in bone. The upper part of the posts was namely integrated in fibrous connective tissue. Osteoid and osteoblast seams could be noted on the surface of the woven bone. However, no osteoid and osteoblasts were identified on the surface of the newly-formed bone situated just under the former membranes. The surface was crenated, having a striking appearance of Howships lacunae. (Fig. 6b). A few osteoclasts were identified. However, there were no signs of remodeling. At post level marrow spaces could be noted. The surgically created perforations were filled with Bio-Oss® particles, hematopoietic tissue and woven bone. Numerous vessels were seen in areas with new bone formation as well as in the fibrous connective tissue. The Bio-Oss® particles with close contact to the implant were surrounded by woven bone. Cutting cones with woven bone could be noted. Particles situated at post level were integrated in fibrous connective tissue and surrounded by only a small edge of osteoid. No resorption of the particles could be seen. In addition, inflammatory cells or remnants of the 2 membranes could not be demonstrated. However, a space in the overlying connective tissue indicated the space where the former membranes had been situated (Fig. 6a). There were signs of minor collapse of both membrane types. The overlying tissue seems to be able to displace the membranes down in the area between the 2 posts. There were signs of rupture of 1 of the collagen membranes.

Discussion

The purpose of the preliminary experiment was to study whether complete osseointegration of an individually made commercially pure titanium subperiosteal implant could be obtained concomitant with no large marrow spaces by using Bio-Oss®

and various membrane types. An earlier study showed incomplete osseointegration of subperiosteal implants covered by ePTFE membranes and fibrous integration of subperiosteal implants without ePTFE membranes (Hjørting-Hansen et al. 1995). The bone substitute in this study was used to occupy the space between the implant and the membrane, to support the overlying membrane, and to act as an osteoconductive material. The histological evaluation documented that all subperiosteal implants were completely osseointegrated irrespective of the used membrane type. Three stages of bone maturation were noted, namely woven bone, woven bone replaced by parallel fibered bone in some areas, and finally in other areas bone resorption of bone on one surface and bone apposition on the other surface. The occurrence of woven bone with osteoid and osteoblast seams, also noted around the Bio-Oss® particles indicated that further osteogenesis could be expected if the observation period was extended.

The osteoconductive properties of Bio-Oss® have been documented in earlier studies also (Berglundh & Lindhe 1997; Klinge et al. 1992; Thaller et al. 1993; Storgaard-Jensen et al. 1996). Considerable amounts of new bone were formed in direct contact with the Bio-Oss® particles. On the surface of the particles signs of cutting cones could be noted. Although no osteoclasts were identified, as in previous studies (Klinge et al. 1992; Storgaard-Jensen et al. 1996), evidence of earlier resorption was present due to new bone formation in the central part of some of the particles and in lacunas on the surface of the particles. Consequently, it seems that the particles were participating in the general remodeling processes. Although this study is not an unbiased stereologic study, but a descriptive histologic study, the large marrow spaces as noted in an earlier study (Hjørting-Hansen et al. 1995) were considerably diminished irrespective of the covering membrane type. The combined use of Bio-Oss® covered by a membrane seems to secure more bone formation (Hürzeler et al. 1998; Hämmerle et al. 1997) compared to the use of only a membrane, as previously documented (Hjørting-Hansen et al. 1995). This is also in accordance with experiences in vertical augmentations in humans, reported by Simion and coworkers (1994, 1998). By addition of particles of autogenous bone or demineralized freeze-dried allograft, these authors succeeded in an increase of vertical augmentation of the edentulous alveolar process by nearly 100% when the above mentioned chips were used as a filler along with the use of membranes (Simion et al. 1994; Simion et al. 1998).

The study was performed by using rabbit tibia and not resorbed atrophic jaw. Therefore, bone formation would be due to neogenesis rather than regeneration. Lifting and repositioning of the periost will induce a subperiosteal bone reaction in young individuals. This does not occur in adults (Melcher 1971; Melcher & Accursi 1971). Linde and co-workers (1993) placed ePTFE domes on the surface of 3 rat calvaria. The periosteum was excised to reduce the tension of the overlying soft tissue. No new bone formation could be noted. In contrast, if a ePTFE dome was covered by periosteum, new bone formation occurred (Linde et al. 1993). This indicated that the effect of the periosteum is necessary for bone formation. However, studies using different kinds of titanium devices have indicated, that there is no need for a periosteum to induce bone formation (Lundgren et al. 1995; Schmid et al. 1994). In the present study perforations of the cortical bone were made to enable osteoprogenitor cells from the tibia marrow to emerge into the experimental area. This procedure is in accordance with some studies (Alberius et al. 1996; Buser et al. 1990; Hämmerle et al. 1997; Linde et al. 1993; Schmid et al. 1991; Schmid et al. 1994, Schmid et al. 1997a; Schmid et al. 1997b), while other studies reported bone formation beyond the skeletal envelope without cortical bone perforation (Kostopoulos & Karring 1994a; Kostopoulos & Karring 1994b; Lundgren et al. 1995). The surgically created perforations were filled with woven bone and hematopoietic tissue in contact with the marrow of the tibia indicating that osteoprogenitor cells had possibilities to invade the supraimplant area. No quantitative studies have to our knowledge compared the amount of newly-formed bone with or without perforating the bone surface.

The stability of the wound area and/or the stability of the membrane is a crucial point in bone formation too. Linde and co-workers concluded that the stiffer the dome material, the more the new bone formation (Linde et al. 1993). This is in accordance with titanium device studies (Lundgren et al. 1995; Schmid et al. 1994) and studies where the membrane is stabilized by a bone substitute (Hürzeler et al. 1998; Hämmerle et al. 1997; Schmid et al. 1997a; Schmid et al. 1997b).

The ePTFE membranes showed no signs of collapse and adjacent inflammatory reactions. Consequently, the material again proved to be highly biocompatible (Becmeur et al. 1990; Dahlin et al. 1988; Dahlin et al. 1990; Schenk et al. 1994). Newly-formed bone was noted occasionally on the outer surface of the membrane. The 2 degradable membranes both showed signs of minor collapse. The collapse did not impair bone formation due to the supporting Bio-Oss® particles. There were

signs of resorption of the newly-formed bone which had been in former contact with both the degradable membranes. An earlier study showed no such signs (Aaboe et al. 1998). However, the observation period was only 8 weeks in that study. The extended observation period could therefore explain the bone resorption due to a more advanced stage of degradation. Hürzeler and co-workers (1998) treated exposed implant threads in monkey with Bio-Oss® and Bio-Gide® or ePTFE membranes. Resorption of the Bio-Oss® particles lying directly underneath the Bio-Gide® membrane were noted after 6 months. This was not noted of Bio-Oss® particles under a ePTFE membrane (Hürzeler et al. 1998). It is possible that the degradation products creates an environment which attracts osteoclast-like cells. Another reason for the resorption could be the obtained contact with periost after the degradation. However, it is not possible to document the above-mentioned possibilities.

It is unknown whether newly-formed bone persist in an area where it is not normally expected. One study performed on the lateral surface of rat mandible has indicated persistence of the newly-formed bone after 6 months (Lioubavina et al. 1994). However, no studies have been performed loading the bone formed beyond the skeletal envelope. The question is: Will bone formed on a extremely atrophic jaw around a subperiosteal implant persist? Will it persist if loaded? It is known that transplanted autogenous bone resorb to a certain degree (Baker et al. 1979; Burchardt 1987; Swart & Allard 1985). However, the resorption of normal bone will be reduced if implants are inserted and loaded (von Wowern et al. 1990). This could be the same for bone formed around a loaded osseointegrated subperiosteal implant.

Conclusion

It should be emphasized that the present study is a preliminary, descriptive, histologic study. No statistical analysis has been made. However, the combined use of a bone substitute together with different membranes ensured complete osseointegration of the subperiosteal implants. In addition, the marrow spaces seem diminished. Further studies should focus on loading of the osseointegrated subperiosteal implants.

Acknowledgement

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Résumé

Une étude précédente a mis en évidence une ostéointégration incomplète d'implants individuels en titane sous-périostés recouverts par une membrane en téflon et fixés à la surface osseuse du tibia du lapin. Le nouvel os formé était en plus dominé par de larges espaces spongieux. Dans l'étude présente des implants sous-périostés ont également été fixés sur la surface osseuse de deux tibias de neuf lapins blancs de Copenhague. Des particules de Bio-Oss® ont été condensées pour recouvrir l'entièreté de la surface implantaire. Au dessus, une des trois membranes suivantes a été placée: la Polyglactin 910® bioabsorbable, une membrane collagène à double couche bioabsorbable et la membrane en téflon. Des coupes sans décalcification ont été préparées pour l'évaluation histologique après douze semaines d'observation. Les 18 implants étaient complètement ostéointégrés. De plus les espaces de l'os spongieux étaient réduits comparés à ceux observés dans l'étude précédente. Les particules de Bio-Oss® étaient biocompatibles et ostéoconductives. Les membranes en téflon ne montraient pas de signe d'affaissement, ni d'infiltration adjacente de cellules inflammatoires. La membrane Polyglactin 910® et la membrane collagène à double couche s'étaient légèrement affaissées. Il y avait des signes de résorption à la surface de l'os néoformé sous les membranes dégradables. La cause de cette résorption n'a pu être prouvée.

Zusammenfassung

Eine frühere Studie zeigte bei individuell hergestellten subperiostalen Titanimplantaten, die mit einer ePTFE-Membran abgedeckt und auf der Knochenoberfläche der Tibia eines Kaninchens fixiert worden waren, eine unvollständige Osseointegration. Zusätzlich bestand der neugebildete Knochen vornehmlich aus grossen Markräumen. In der nachfolgenden Studie wurden ebenfalls subperiostale Implantate auf die Oberfläche der zwei Tibiaknochen von 9 weissen Kaninchen fixiert. Dann kondensierte man Bio-Oss®-Partikel dicht um das Implantat herum, so dass die Oberfläche vollständig bedeckt war. Eine von drei verschiedenen Membranen bedeckte das Implantat und die Partikel. Die verwendeten Membranen waren ein abbaubares Polyglactin 910®-Netz, eine abbaubare doppellagige Kollagenmembran und eine nicht abbaubare ePTFE-Membran. Nach einer 12-wöchigen Beobachtungsphase wurden nichtentkalkte Schnitte für die histologische Untersuchung vorbereitet. Alle 18 subperiostalen Implantate waren vollständig osseointegriert. Zusätzlich konnte der Markraumanteil gegenüber unseren vorhergehenden Studien reduziert werden. Die Bio-Oss®-Partikel erwiesen sich als biokompatibel und osteokonduktiv. Die ePTFE-Membranen zeigten weder Anzeichen eines Kollabierens, noch eine randständige Infiltration von Entzündungszellen. Die Polyglactin®-Netze und die doppellagigen Kollagenmembranen kollabierten leicht. Man fand Anzeichen einer oberflächlichen Resorption der abbaubaren Membranen und des darunterliegenden neu gebildeten Knochens. Die Ursache der Resorption kann nicht dokumentiert werden.

Resumen

Un estudio anterior reveló una incompleta osteointegración de implantes de titanio subperiosticos hechos individualmente cubiertos por ePTFE y fijados a la superficie del hueso tibial del conejo. Además, el hueso neoformado estaba dominado por grandes espacios de médula. En el siguente estudio también se

fijaron implantes subperiósticos en la superficie ósea de ambas tibias de 9 conejos blancos de Copenhague. Se compactaron partículas de Bio-Oss® cubriendo toda la superficie implantaria. Una de tres diferentes membranas cubrió el implante y las partículas. Las membranas usadas fueron una malla de Polyglactin 910® degradable, una membrana de colágeno degradable de doble capa y una membrana no degradable de ePTFE. Se prepararon secciones no descalcificadas para evaluaciones histológicas tras un periodo de observación de 12 semanas. Todos los 18 implantes subperiosticos estaban completamente osteointegrados, además, los espacios medulares se redujeron comparados con el estudio anterior. Las partículas de Bio-Oss demostraron ser biocompatibles y osteconductivas. Las membranas de ePTFE no revelaron signos de colapso ni de infiltración adyacente de células inflamatorias. La malla de Polyglactin 910 y la membrana de colágeno de doble capa se colapsaron ligeramente. Hubo signos de reabsorción de la superficie del hueso neoformado bajo las membranas degradables. La causa de la reabsorción no puede se documentada.

要旨

前回の研究では個々に製作し、ePTFE メンブレンで被覆し、家兎の脛骨表面に固定したチタン製骨膜下インプラントの骨性統合は不完全であった。さらに新生骨の多くは大きな髄腔が占めていた。

前回に続く本研究では、骨膜下インプラントを９匹の Copenhagen White rabbit の脛骨表面に固定した。インプラント表面全体を覆うように Bio-Oss ®の粒子を緻密に埋めこんだ。三種の異なるメンブレンの一つを用いて、インプラントと粒子を被覆した。使用したメンブレンは、吸収性の Polyglactin 910®メッシュ、吸収性二層性コラーゲン・メンブレン、及び非吸収性の ePTFE メンブレンであった。１２週間の観察期間後、非脱灰切片を準備して組織学的評価を行った。

１８個の骨膜下インプラントは全て完全に骨性統合を達成した。さらに我々の前回の研究に比べて髄腔は減少した。Bio-Oss® の粒子は生体適合性があり骨伝導性であることが証明された。

ｅPTFE メンブレンに、圧壊や隣接部の炎症細胞浸潤の徴候はなかった。Polyglactin 910 メッシュ及び二層性コラーゲン・メンブレンはわずかに圧壊していた。吸収性メンブレン下の新生骨表面には吸収の徴候が認められた。吸収の原因は究明できなかった。

References

Aaboe, M., Pinholt, E.M., Schou, S. & Hjørting-Hansen, E. (1998) Incomplete bone regeneration of rabbit calvarial defects using different membranes. *Clinical Oral Implants Research* **9**: 313–320.

Alberius, P., Gordh, M., Lindberg, L. & Johnell, O. (1996) Effect of cortical perforations of both graft and host bed on onlay incorporation to the rat tibia. *European Journal of Oral Sciences* **104**: 554–561.

Albrektsson, T., Zarb, G., Worthington, P. & Eriksson, A.R. (1986) The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *International Journal of Oral and Maxillofacial Implants* **1**: 11–25.

Baker, R.D., Terry, B.C., Davis, W.H. & Cannole, P.W. (1979) Long-term results of alveolar ridge augmentation. *Journal of Oral Surgery* **37**: 486–489.

Becmeur, F., Geiss, S., Laustriat, S., Bientz, J., Marcellin, L. & Sauvage, P. (1990) Histology of teflon. *European Urology* **17**: 299–300.

Berglundh, T. & Lindhe, J. (1997) Healing around implants placed in bone defects treated with Bio-Oss®. An experimental study in the dog. *Clinical Oral Implants Research* **8**: 177–124.

Block, M.S. & Kent, J.N. (1985) Healing of mandibular ridge augmentations using hydroxyapatite with and without bone in dogs. *Journal of Oral and Maxillofacial Surgery* **43**: 3–7.

Burchardt, H. (1987) Biology of bone transplantation. *Orthopedic Clinics of North America* **18**: 187–196.

Buser, D., Brägger, U., Lang, N.P. & Nyman, S. (1990) Regeneration and enlargement of jaw bone using guided tissue regeneration. *Clinical Oral Implants Research* **1**: 22–32.

Dahlin, C., Linde, A., Gottlow, J. & Nyman, S. (1988) Healing of bone defects by guided tissue regeneration. *Journal of Plastic and Reconstructive Surgery* **81**: 672–767.

Dahlin, C., Gottlow, J., Linde, A. & Nyman, S. (1990) Healing of maxillary and mandibular bone defects using a membrane technique: an experimental study in monkeys. *Scandinavian Journal of Plastic and Reconstructive Hand Surgery* **24**: 13–19.

Frame, J.W. (1987) Ridge augmentation using solid and porous hydroxyapatite particles with and without autogenous bone or plaster. *Journal of Oral and Maxillofacial Surgery* **45**: 771–777.

Gotfredsen, K., Budtz-Jørgensen, E. & Nimb Jensen, L. (1989) A method for preparing and staining histological sections containing titanium implants for light microscopy. *Staining Technology* **64**: 121–127.

Gotfredsen, K., Warrer, K., Hjørting-Hansen, E. & Karring, T. (1991) Effect of membranes and hydroxyapatite on healing in bone defects around titanium dental implants. *Clinical Oral Implants Research* **2**: 172–178.

Hjørting-Hansen, E., Helbo, M., Aaboe, M., Gotfredsen, K. & Pinholt, E.M. (1995) Osseointegration of subperiosteal implant via guided tissue regeneration. A pilot study. *Clinical Oral Implants Research* **6**: 149–154.

Hürzeler, M.B., Kohal, R.J., Naghshbandi, J., Mota, L.F., Conradt, J., Hutmacher, D. & Caffesse, R.G. (1998) Evaluation of a new bioresorbable barrier to facilitate guided bone regeneration around exposed implant threads. An experimental study in the monkey. *International Journal of Oral and Maxillofacial Surgery* **27**. (In press.)

Hammerle, C.H.F., Olah, A.J., Schmid, J., Flückiger, L., Gogolewski, S., Winkler, J.R. & Lang, N.P. (1997) The biological effect of natural bone mineral on bone neoformation on the rabbit skull. *Clinical Oral Implants Research* **8**: 198–207.

Klinge, B., Alberius, P., Isaksson, S. & Jönsson, J. (1992) Osseous response to implanted natural bone mineral and synthetic hydroxylapatite ceramic in the repair of experimental skull bone defects. *Journal of Oral and Maxillofacial Surgery* **50**: 241–249.

Kostopoulos, L. & Karring, T. (1994a) Augmentation of the rat mandible using guided tissue regeneration. *Clinical Oral Implants Research* **5**: 75–82.

Kostopoulos, L., Karring, T. & Uraguchi, R. (1994b) Formation of jawbone tuberosities by guided tissue regeneration. An experimental study in the rat. *Clinical Oral Implants Research* **5**: 245–253.

Lioubavina, N., Kostopoulos, L. & Karring, T. (1994) Long

term stability of jaw bone tuberosities produced according to the principle of "guided tissue regeneration". An experiment in the rat. Abstract: 51 Europerio 1, Paris, 1994.

Linde, A., Thorén, C., Dahlin, C. & Sandberg, E. (1993) Creation of new bone by an osteopromotive membrane technique: an experimental study in rats. *Journal of Oral and Maxillofacial Surgery* **51**: 892–897.

Lundgren, D., Lundgren, A.K., Sennerby, L. & Nyman S. (1995) Augmentation of intramenbraneous bone beyond the skeletal envelope using an occlusive titanium barrier. *Clinical Oral Implants Research* **6**: 67–72.

Melcher, A.H. (1971) Wound healing in monkey (*Macaca Irus*) mandible: effect of elevating periosteum on formation of subperiosteal callus. *Archives of Oral Biology* **16**: 461–464.

Melcher, A.H. & Accursi, G.E. (1971) Osteogenic capacity of periosteal and osteoperiosteal flaps elevated from the parietal bone of the rat. *Archives of Oral Biology* **16**: 573–580.

Moy, P., Lundgren, S. & Holmes, R.E. (1993) Maxillary sinus augmentation: Histomorphometric analysis of graft materials for maxillary sinus floor augmentation. *Journal of Oral and Maxillofacial Surgery* **51**: 857–862.

Ripamonti, U. (1992) Calvarial reconstruction in baboons with porous hydroxyapatite. *Journal of Craniofacial Surgery* **3**: 149–159.

Schenk, R.K., Buser, D., Hardwick, W.R. & Dahlin, C. (1994) Healing pattern of bone regeneration in membrane-protected defects: a histologic study in the canine mandible. *International Journal of Oral and Maxillofacial Implants* **9**: 13–29.

Schmid, J., Hämmerle, C.H.F., Stich, H. & Lang, N.P. (1991) Supraplant®, a novel implant system based on the principle of guided bone generation. A preliminary study in the rabbit. *Clinical Oral Implants Research* **2**: 199–202.

Schmid, J., Hämmerle, C.H.F., Olah, A.J. & Lang, N.P. (1994) Membrane permeability is unnecessary for guided generation of new bone. An experimental study in the rabbit. *Clinical Oral Implants Research* **5**: 125–130.

Schmid, J., Hämmerle, C.H.F., Flückiger, L., Winkler, J.R., Olah, A.J., Gogolewski, S. & Lang, N.P. (1997a) Blood-filled spaces with and without filler materials in guided bone regeneration. A comparative experimental study in the rabbit using bioresorbable membranes. *Clinical Oral Implants Research* **8**: 75–81.

Schmid, J., Wallkamm, B., Hämmerle, C.H.F., Gogolewski, S. & Lang, N.P. (1997b) The significance of angiogenesis in guided bone regeneration. A case report of a rabbit experiment. *Clinical Oral Implants Research* **8**: 244–248.

Simion, M., Trisi, P. & Piattelli, A. (1994) Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. *International Journal of Periodontology and Restorative Dentistry* **14**: 497–511.

Simion, M., Jovanovic, S.A., Trisi, P., Scarano, A. & Piattelli, A. (1998) Vertical ridge augmentation around dental implants using a membranes technique and autogenous bone or allog rafts in humans. *International Journal of Periodontology and Restorative Dentistry* **18**: 9–23.

Storgaard-Jensen, S., Aaboe, M., Pinholt, E.M., Hjørting-Hansen, E., Melsen, F. & Ruyter, I.E. (1996) Tissue reaction and material characteristics of four bone substitutes. *International Journal of Oral and Maxillofacial Implants* **11**: 55–66.

Swart, J.G.N. & Allard, R.H.B. (1985) Subperiosteal onlay augmentation of the mandible: a clinical and radiographic survey. *Journal of Oral and Maxillofacial Surgery* **43**: 183–187.

Thaller, S.R., Hoyt, J., Bonjeson, K., Dart, A. & Tesluk, H. (1993) Reconstruction of calvarial defects with anorganic bovine bone mineral (Bio Oss) in a rabbit model. *The Journal of Craniofacial Surgery* **4**: 79–84.

von Wovern, N., Harder, F., Hjørting-Hansen, E. & Gotfredsen, K. (1990) ITI implants with overdentures: a prevention of bone loss in edentulous mandibles? *International Journal of Oral and Maxillofacial Implants* **5**: 135–139.

Wetzel, A.C., Stich, H. & Cafesse, R.G. (1995) Bone apposition onto oral implants in the sinus area filled with different grafting material. *Clinical Oral Implants Research* **6**: 155–163.

Zitzmann, N.U., Naef, R. & Schärer, P. (1997) Resorbable versus non-resorbable membranes in combination with Bio Oss® for guided bone regeneration. *International Journal of Oral and Maxillofacial Implants* **12**: 844–852.