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Effect of bioresorbable fibres (Polyfibre®) and a bioresorbable foam (Polyfoam®) on new bone formation

A short term experimental study on the rabbit skull

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Key words: guided bone regeneration, new bone formation, polylactic acid membrane, polylactic acid filler, xenogenic bone substitute material, rabbit

Abstract: The aim of the study was to evaluate two bioresorbable polylactic acid (PLA) filler materials in a guided bone regeneration (GBR) model system. The first was Polyfibre®, a fibrous PLA filler material. Polyfoam®, the second material tested, consisted of a spongy PLA filler material. In each group there were eight rabbits. In test rabbits a flap was raised uncovering the calvaria. A hemispherical PLA dome was filled with Polyfibre® or Polyfoam® material and peripheral blood and anchored onto the calvaria. Eight rabbits with the same domes, filled with blood alone, served as controls. The rabbits were sacrificed at 1 or 2 months. Histomorphometric measurements of regenerated total tissue volume, bone height and bone volume were carried out in undecalcified sections under a light microscope. At 1 month the totally filled volume attained 87% (range 82–91) in the fibre group, including 25% (23–27) fibres, 87% (85–95) in the foam group, including 15% (15–16) foam, and 55% (16–100) in the controls. The volume of mineralized bone was 12% (7–15) in the fibre group, 15% (12–18) in the foam group and 6% (1–11) in control domes. Bone height attained 48% (27–79) in the fibre group, 37% (31–58) in the foam group and 45% (14–67) in the control group. At 2 months, tissue volume attained 86% (85–87) including 26% (22–29) fibres, bone volume attained 13% (7–21) and bone height attained 56% (42–78) in the Polyfibre® group. In the Polyfoam® group, they were 83% (55–99) including 18% (15–19) foam, 13% (7–24) and 49% (29–74). In control domes, tissue volume was 82% (35–100), bone volume 20% (9–27) and bone height 86% (60–100). The Polyfibre® and Polyfoam® material was excellently integrated. No adverse reactions were found in the surrounding tissues. Direct bone apposition was observed onto the material. In conclusion, Polyfibre® and Polyfoam® material had a positive effect on initial bone and tissue formation but was a hindrance to increasing tissue volume, bone volume or bone height at 2 months compared to control specimens. The Polyfibre® and Polyfoam® material provoked no adverse reactions in the surrounding tissues and allowed for extensive angiogenesis.

The regeneration of damaged or lost tissue is one of the major scopes in modern medicine. More than a decade ago, the principle of guided tissue regeneration (GTR) was first successfully applied to regenerate periodontal tissues. Later the method of guided bone regeneration (GBR) has been established as a successful procedure to augment the volume of the jawbone prior to implant placement (Buser et al. 1990; Nyman et al. 1990; Lang et al. 1994).

Parts of the alveolar process may be resorbed after trauma, by pathological processes or as a physiological adaptation in consequence of tooth loss. Prior to implant instalment, such unfavourable conditions may be improved by extensive surgical procedures such as sinus-lift opera-

tions (Tatum 1987; Smiler et al. 1992; Wetzel et al. 1995), nerve transposition (Rosenquist 1992) and bone onlay grafts from the iliac crest or from the skull (Hardt & Grau 1990). These procedures are severe interventions and considerable side effects have been reported (Regeev et al. 1995).

In many cases, the technique of GBR allows one to achieve a sufficient amount of new bone and the surgical risks are comparatively low. In view of the necessity to instal titanium implants for a prosthodontic oral rehabilitation, there is an increasing need to regenerate lost alveolar bone. According to the principles of GBR, an empty space has to be created into which osteoprogenitor cells may migrate and gradually form new bone (Nyman 1991). All undesired cells are being excluded by means of a barrier membrane. For the stabilization of this space and support of the membrane, a variety of methods have been advocated: stiff but bendable membrane inclusions, a second stiff titanium mesh and supporting screw devices (Buser et al. 1993; Lundgren et al. 1995). But also bone or bone substitute materials have been placed underneath the membrane such as autogenic bone, xenogenic bone and xenogenic bone substitute materials (Klinge et al. 1992; Hämmerle et al. 1997; Buser et al. 1998; Becker et al. 1995; Mattout et al. 1995; Nevins & Mellonig 1992; Zitzmann et al. 1996; von Arx et al. 1998). While autogenic bone offers many advantages, its harvesting is not without risk, especially in larger quantities. Intraoral sites for harvesting bone are the chin or the retromolar area (von Arx et al. 1997). Xenogenic materials should be biocompatible, preferably bioresorbable, osseoconductive and easily applicable.

Polylactic acids (PLAs) have only recently come into focus as biocompatible and bioresorbable materials, and promising results have been reported (Hutmacher & Hürzeler 1995). This experimental study aims at testing a bioresorbable PLA fibre conglomerate (Polyfibre®) and a bioresorbable PLA spongy foam material (Polyfoam®) in a GBR model system (Hämmerle et al. 1997). This GBR model system has been described first by Frame (1980) and has been shown in many studies to fulfil the requirements of an ideal animal model for testing bone substitute materials.

Material and methods

Surgical procedures and materials

Twenty-four adult rabbits were anaesthetized with Nembutal® (Abbot, Chicago, IL, USA). The top of the head and the base of the left ear were shaved and then disinfected with Sterillium® (Bode, Hamburg, Germany). The area of surgery was infiltrated with Neolidocaton® 2% (Pharmaton, Lugano, Switzerland). A trapezoid incision was made over the skull and a cutaneous flap was raised on the forehead and reflected posteriorly. Similarly, the periosteum was cut and reflected posteriorly exposing the top of the cranial bone. he cutaneous flap and the periosteum were kept moist by covering them with a sterile, saline-filled gauze. In between the sagittal and coronal sutures on the left side, where the dome was to be placed, the external cortical plate in a diameter corresponding to the base of the dome was carefully removed using a round bur in a dental handpiece irrigating sufficiently with sterile saline. Care was taken to avoid involvement of the sagittal and coronal sutures. The experimental device consisted of a form-stable, custom-made hemispherical dome made of PLA, specifically of poly(l)-lactide, ethanol sterilized. The domes had a height of 5 mm, a thickness of 0.5 mm and a basal rim extending 3–4 mm from the basal borders of the domes. All of them were exactly of the same size. The rim was trimmed to fit the individual site and to adapt tightly to the calvaria surface. It was anchored to the calvaria by means of mini-screws (Novimed, Oetwil, Switzerland) (Fig. 1). Prior to placement, the dome was either filled with periphereal blood taken from a vein of the rabbit's left ear (control group (C), eight animals) or with blood and Polyfibre® material (test group 1 (T1), eight animals) or with blood and Polyfoam® material (test group 2 (T2), eight animals). Polyfibre® (Fig. 2) is a bioresorbable fibrous conglomerate consisting of poly(l/DL)-lactic acid in a ratio of 80%/20% (AO/ASIF Research Center, Davos, Switzerland). Polyfoam® (Fig. 3) is a bioresorbable spongy filler material also consisting of poly(L/DL)-lactic acid in a ratio of 80%/20% (AO/ASIF Research Center, Davos, Switzerland). Both materials were ethanol sterilized. The periosteum was sutured over the dome and the borders of the rim with a resorbable suture material (Vicryl®, Johnson & Johnson, Spreitenbach, Switzerland). The cutaneous flap was adapted and sutured with polyamid (Supramid®, Braun-SSC, Emmenbrücke, Switzerland). One month later, four animals of each group were sacrificed by stunning with exsanguination. Two months following surgery, the remaining animals, four per group, were sacrificed in the same way.

Histologic preparation

The calvariae were dissected and fixed in 4% neutral buffered formalin for at least 48 h. The specimens were then rinsed under running tap water dehydrated in a graded series of increasing ethanol concentrations. After random rotation around the vertical axis of the dome, they were embedded in methylmethacrylate without prior decalcification. The tissue blocks were cut into 200-μm-thick vertical sections using a slow-speed diamond saw (Varicut® VC 50, Leco, Munich, Germany). The sections were ground and polished to a final thickness of 80–100 μm (Knuth-Rotor-3, Struers, Rodovre/Copenhagen, Denmark) and surface stained with toluidine blue (Schenk et al. 1984).

Histomorphometry

From each specimen the most central section was selected for qualitative assessment of the different tissue components by applying standard morphometrical techniques (Weibel 1980). Measurements were carried out directly in the light microscope at a magnification of × 63, using an optically superimposed eyepiece test grid composed of 100 points and 10 cycloid lines (Schenk & Olah 1980; Weibel 1980). The number of test points overlying the profiles of the different components (mineralized new bone (B), connective tissues (CT), Polyfibre® material (Pfi), Polyfoam® material (Pfo) and empty space (E)) was counted and related to the total submembraneous space (Hämmerle et al. 1997). In addition, the maximal height of the regenerated bone was determined and expressed as the percentage of the total height of the space below the dome. In a subset of specimens, the morphometric analysis was performed twice in order to determine the reproducibility of the method employed.

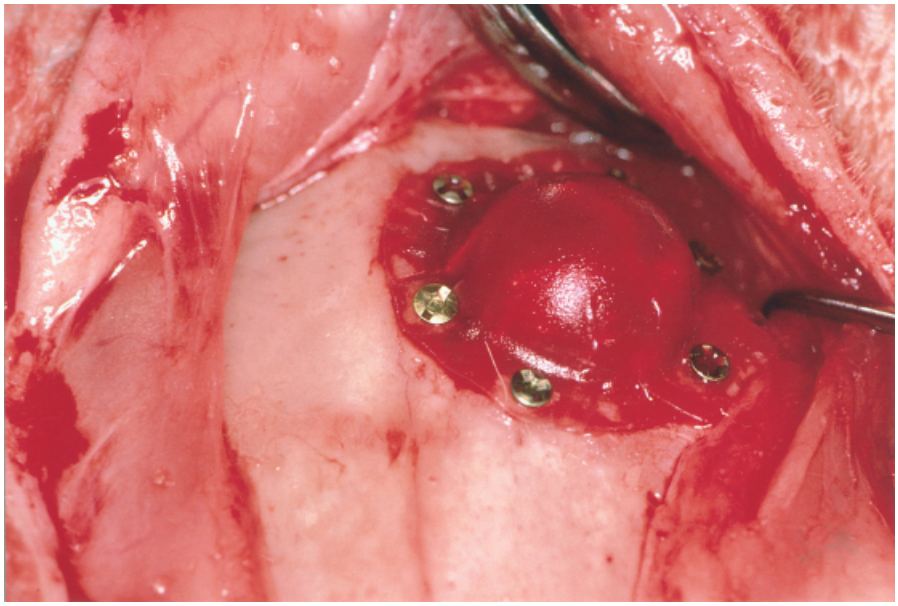

Fig. 1. Experimental hemispherical dome made of polylactic acid (PLA), specifically of poly(l)-lactide, anchored to the calvaria by means of mini-screws.

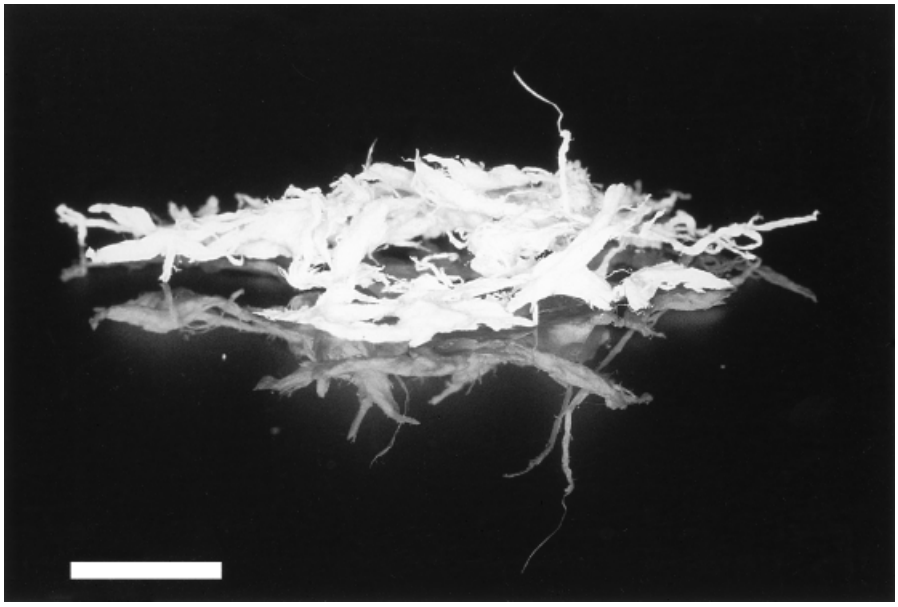

Fig. 2. Polyfibre® is a bioresorbable fibrous conglomerate consisting of poly(l/dl)-lactic acid in a ratio of 80%/20%. The length of the white bar is 5 mm.

Results

In all rabbits, the surgical sites healed uneventfully with no signs of inflammation. No adverse reactions were observed and all 24 rabbits behaved normally throughout the course of the study. When removing the part of the skull with the dome, no signs of inflammation or other undesired reactions could be observed in the tissues. All PLA domes were excellently integrated and had maintained their shape. No disintegration of the membrane could be detected.

One-month specimens

At low microscopic magnification, the original shape and texture of the PLA domes appeared to be well conserved in all groups. There were no signs of resorption or dissolution of the domes.

In the Polyfibre® group (T1), the entire dome was filled with 25% (range: 23–27) Polyfibre® material surrounded by newly formed soft and hard tissue. An extensive network of blood vessels occupied the spaces between the filler material. New bone trabeculae were extending from the calvaria into the dome area. These trabeculae seemed to be intimately associated with the blood vessels (Fig. 4). At higher magnification a clear distinction could be made between calvaria, newly formed bone, Polyfibre® material, connective tissue and empty space. The respective areas were calculated (Table 1). New tissue including soft and hard tissue and the PLA material occupied 87% (82–91) of the total space available under the dome. The remaining space seemed to be empty but most likely filled with serum with some cell debris. The volume of newly formed bone attained 12% (7–15) and the height of this bone attained 48% (27–51) compared to the total available height under the dome. The different tissues grew around the PLA fibres without adverse reactions. No signs of resorption of the fibres were observed at this time point.

In the Polyfoam® group (T2), the domes were filled with 15% (15–16) Polyfoam® material surrounded by newly formed soft and hard tissue. Also in this group we found a consistent filling of the domes with foam material. Newly formed blood vessels and connective tissue occupied the space between the spongy filler material. The trabecular structure of the newly formed bone was denser than both in the original calvaria and the control specimens (Fig. 5). At higher magnification a clear distinction could be made between calvaria, newly formed bone, Polyfoam® material, connective tissue and empty space in this group as well. The respective areas were calculated (Table 1). New tissue including soft and hard tissue and the PLA material occupied 87% (85–95) of the total space available under the dome. Also in this group the remaining space seemed to be empty but most likely filled with serum. The volume of newly formed bone attained 15% (12–18) and the height of this bone attained 37% (31–58) compared to the total available height under the dome. The different tissues grew in between the foam particles without adverse reactions. No signs of resorption of the foam were observed.

Considerable variation in the amount of hard and soft tissue regeneration was

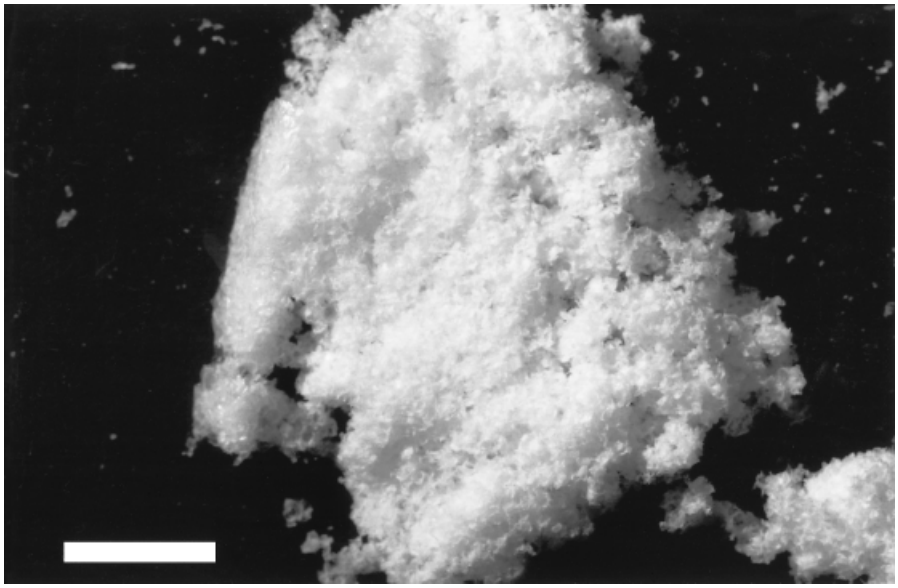

Fig. 3. Polyfoam® is a bioresorbable spongy filler material also consisting of poly(l/dl)-lactic acid in a ratio of 80%/20%. The length of the white bar is 5 mm.

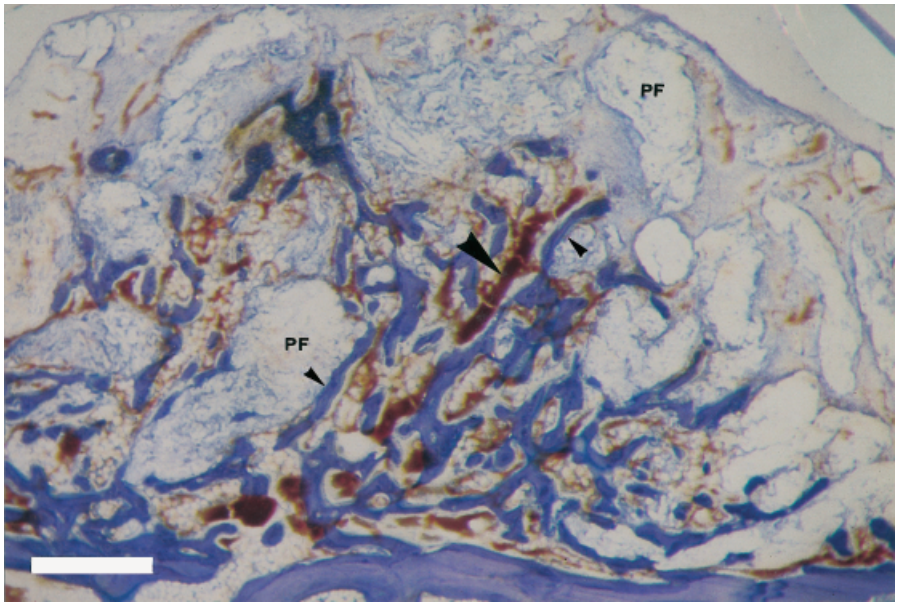

Fig. 4. Central vertical section through a PLA dome filled with Polyfibre® (PF) and regenerated tissue at 1 month. New bone trabeculae (small arrows) were extending from the calvaria into the dome area. These trabeculae seemed to be intimately associated with the blood vessels (large arrow). Nondecalcified ground section. Haematoxylin-eosin/toluidine blue stain. The length of the white bar is 1 mm.

observed in the control specimens (Table 1). In one sample, newly formed soft tissue occupied the entire space under the dome and a remarkable amount of new bone was observed (11%). Other specimens demonstrated only minimal new tissue formation (16%) and the newly formed bone did not rise much above the former calvaria surface (14%). The area occupied by newly formed soft and bone tissue related to the total space available comprised on average 55% (16–100). The bone tissue occupied an area of 6% (1–11) and the upper front of new bone reached a height of 45% (14–67) of the submembraneous space.

Two-month specimens

At this time point, the original shape and texture of the PLA domes appeared to be well conserved in all groups. Again there were no signs of resorption or dissolution of the domes. In the Polyfibre®-filled domes the newly formed tissue occupied an area of 86% (85–87) including 26% (22–29) fibre material. 13% (7–21) of the space was filled with bone, which reached a height of 56% (42–78) (Table 1).

In the Polyfoam®-filled specimens there was a tissue filling of 83% (55–99) under the domes, including 18% (15–19) foam material and 13% (7–24) new bone. The frontline of new bone attained 49% (29–74) in height (Table 1). The domes in the control group were filled with 82% (35–100) newly formed tissue. 20% (9–27) was new bone, which attained a height of 86% (60–100) (Table 1).

Nowhere in all eight test specimens could there be found adverse reactions to the PLA filler materials. The fibres and the foam were well integrated in the newly formed tissues (Fig. 6). None of them showed signs of resorption or dissolution.

From 1 to 2 months

Bone height increased in the test and control sites (Fig. 7). Bone volume increased slightly in the Polyfibre® group. In the Polyfoam® group the volume of newly formed bone decreased slightly. In the control group bone volume increased much more (Fig. 8). The total tissue volume increased only in the control group. In the two test groups, the volume of newly formed tissue decreased slightly. In two control specimens the height of new bone attained even the top of the available space under the dome. This result was never observed in test specimens. In the test groups the generation of new tissues was much faster in the first month than in the second period. In the control specimens tissue volume and bone height was increasing constantly in this 2-month period. The volume replaced with Polyfibre® material was similar in all the test domes. In the Polyfoam® group the volume occupied by the foam was also very similar in all test specimens.

New bone formation resulted in woven bone exhibiting a trabecular pattern in both test and control specimens. Fibrous connective tissue rich in blood vessels filled the spaces in between the bone trabeculae.

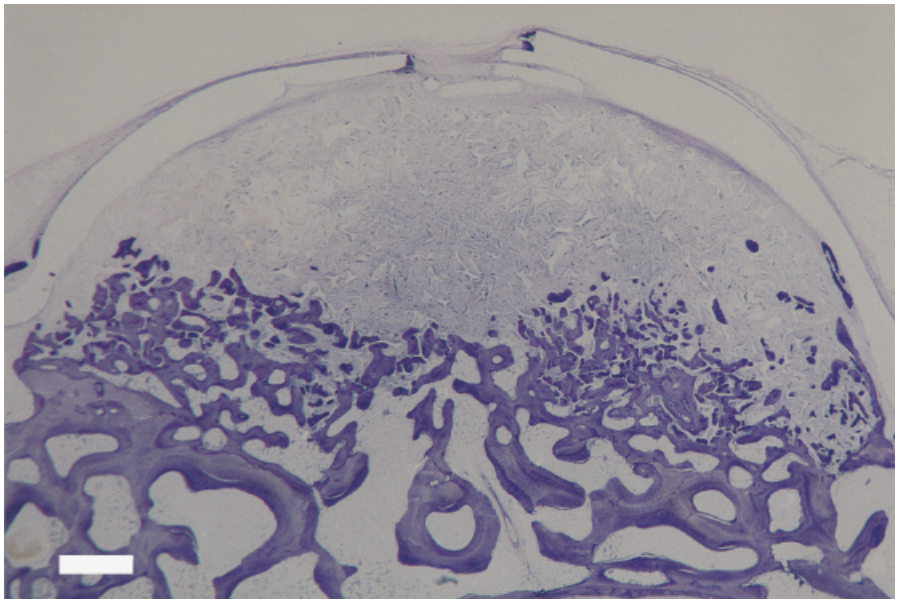

Fig. 5. Trabecular structure of the newly formed bone in this Polyfoam® specimen looks denser than both in the original calvaria and the control specimens. Nondecalcified ground section. Toluidine blue stain. The length of the white bar is 1 mm.

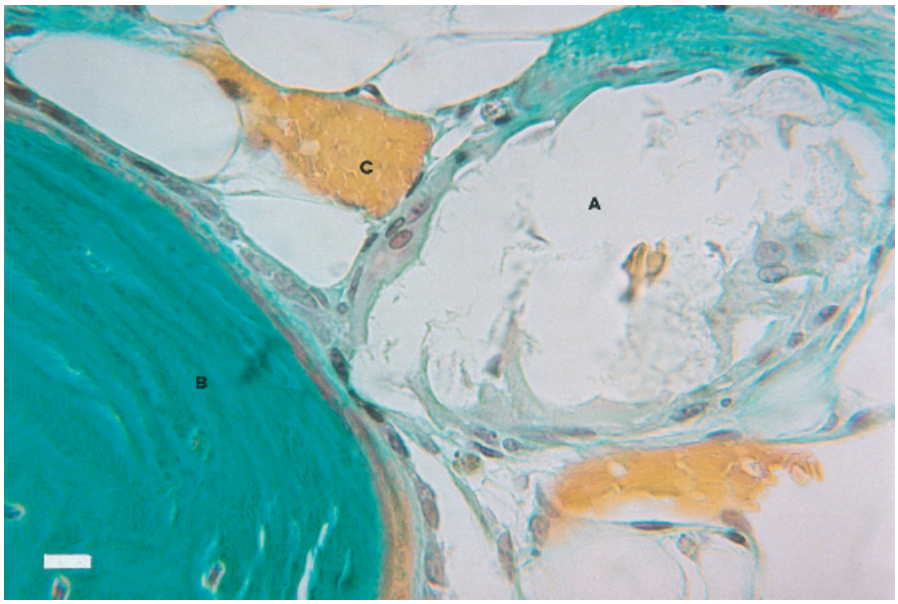

Fig. 6. In all eight test specimens, adverse reactions to the PLA filler materials could not be found. Polyfibre® material seems to be well integrated in the connective tissue. Nondecalcified ground section. Goldner stain. The length of white bar is 0.1 mm. A: Polyfibre®; B: new bone; C: vessel.

***Table 1.* Tissue volume, bone volume, PLA volume and bone height in relation to total space available under the domes (volume fraction)**

	Number of specimens	PLA (%)	Bone (%)	Tissue and PLA (%)	Bone height (%)
1 months					
Polyfibre® (Test 1)	4	25 (23–27)	12 (7–15)	87 (82–91)	48 (27–51)
Polyfoam® (Test 2)	4	15 (15–16)	15 (12–18)	87 (85–95)	37 (31–58)
Control	4	0	6 (1–11)	55 (16–100)	45 (14–67)
2 months					
Polyfibre® (Test 1)	4	26 (22–29)	13 (7–21)	86 (85–87)	56 (42–78)
Polyfoam® (Test 2)	4	18 (15–19)	13 (7–24)	83 (55–99)	49 (29–74)
Control	4	0	20 (9–27)	82 (35–100)	86 (60–100)

Discussion

As shown in previous studies, the stiff dome-shaped membrane made of polylactic acid used in this experiment was well tolerated by bone and soft tissues (Hämmerle et al. 1997; Schmid et al. 1997a, 1997b). The shape of these membranes was maintained during the 8 weeks of this study. No signs of resorption could be found after 2 months.

New formation of hard and soft tissue occurred in all samples. Within the control group there were huge individual variations in the amount of newly formed tissues. The total volume of newly formed tissue varied from 'completely filled' in some specimens to almost no filling in some other specimens independent of the regeneration time.

Presumably the first days and weeks are crucial for the establishment of an environment favourable for bone regeneration. As shown in a previous paper (Schmid et al. 1997b), a requirement for future ossification is ingrowth of new blood vessels and early proliferation of loose connective tissue into this space to be regenerated (Fig. 9). This is in accordance with microscopic observations from an intravital bone chamber (Winet 1996) and the results of other studies (Schenk et al. 1994; Hämmerle 1995, 1996). In view of this experimental evidence, in the present experiment, the vessel-rich spongious layer was exposed at the sites where the domes were planned to be fixed onto the calvaria. From the spongious layer large vessels grew into the space under the dome and there branched off into a dense network of smaller vessels. This impressive network would presumably have been much smaller if the source of ingrowing vessels was limited to the small vessels on the bone surface, wounded by tearing off the periosteum. The second important feature seems to be the stabilization of the blood coagulum under the dome. The results demonstrate the positive effect of these filler materials on stabilization of the coagulum and the formation of new tissues at an early stage in that the Polyfoam® and Polyfibre® material seemed to have served as a scaffold. An interesting observation was the close spatial correlation between newly formed vessels and newly formed bone (Fig. 4).

The 1-month results are partially in contrast to the 2-month results when the

amount and height of newly generated bone in control specimens surpassed the amount of bone in the test samples (Figs 7 and 8). These findings may indicate that the presence of such PLA filler materials was felt as an obstacle to increasing bone volumes at later stages.

There was no resorption of Polyfibre® and Polyfoam® material at this point. Similar findings were discussed in previous papers (Schmid et al. 1997a; Hämmerle et al. 1997). They also concluded that an ideal xenogenic bone substitute material should have been resorbed between months 1 and 2 in this model system. Based on our findings in this experiment the time of resorption of these two PLA filler materials should lie in this animal model in between 4 and 6 weeks. The exact resorption time of these materials should be investigated in a future study preferably, in a human GBR model system. In the Polyfoam® group the structure of new bone trabeculae seemed to be denser than in controls (Fig. 5). This could be an interesting observation, considering the installation of implants into regenerated bone, and could open promising perspectives for influencing bone density. This observation should be confirmed and validated in a human model. However, before installing implants most of the filler material should be resorbed to ensure biomechanical stability. Comparing these two PLA filler materials relating to the clinical handling, the Polyfoam® material was easier to apply into the test device. The excellent biological integration of these PLA filler materials (no inflammation or adverse reaction could be found) at an early stage (Fig. 6) is in contrast to other observations, which reported a delay and decrease in angiogenesis and tissue formation under the influence of polylactides-polyglycolide as filler material (Winet 1995).

In conclusion, Polyfibre® and Polyfoam® material is beneficial in new bone and soft tissue formation in GBR at an early stage in this model system. The new tissue formation seems to be more predictable than in controls. Later it does not contribute to increasing bone and soft tissue volume or bone height compared to control sites. The PLA membrane, the Polyfibre® and Polyfoam® material demonstrated excellent tissue integration and allowed for extensive angiogenesis. Since no signs of PLA resorption could be detected after completion of the experiment, no information is available concerning resorption kinetics of the materials employed. Also, the effect of the degradation products on newly formed bone tissue is not yet known.

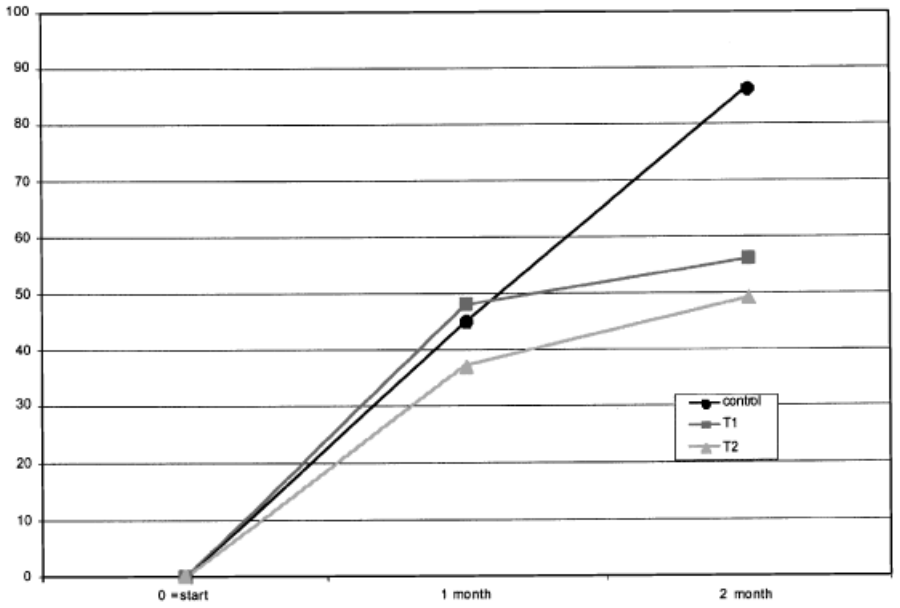

Fig. 7. Bone height in per cent of total height under the dome of control and test groups (T1: polyfibre®; T2: Polyfoam®) after 1 and 2 months.

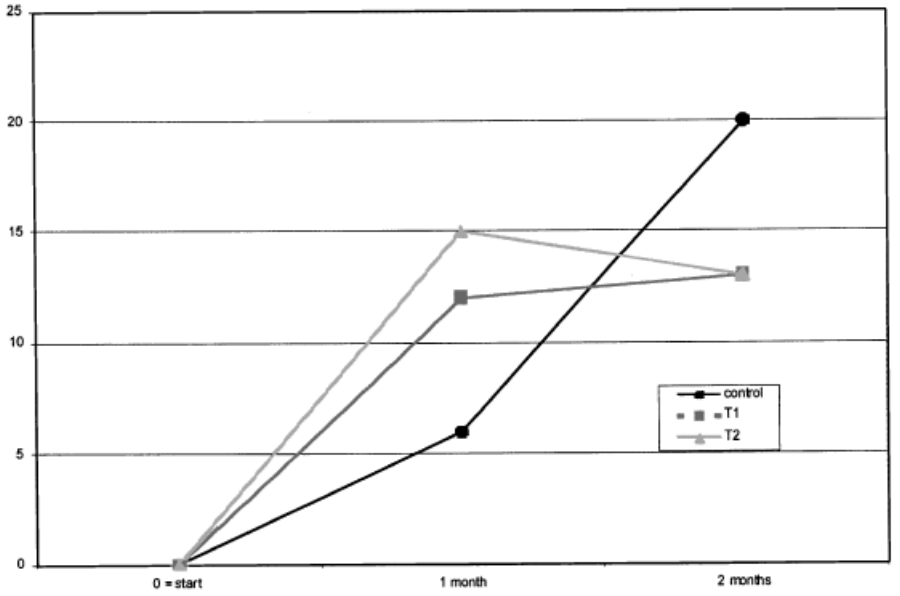

Fig. 8. Bone volume in per cent of total volume available under the dome of control and test groups (T1: Polyfibre®; T2: Polyfoam®) after 1 and 2 months.

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Résumé

Le but de cette étude a été d'évaluer deux matériaux de remplissage en acide polylactide (PLA) biorésorbable dans un modèle de régénération osseuse guidée (GBR). Le premier était le Polyfibre®, un matériau de remplissage PLA fibreux. Le second, le Poly-

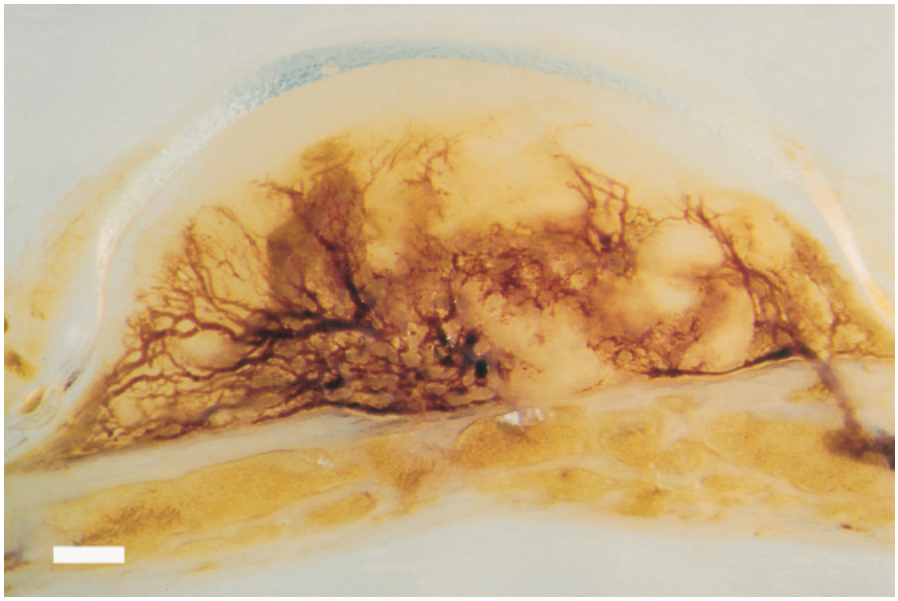

Fig. 9. A requirement for future ossification seems to be the ingrowth of new blood vessels into this space to be regenerated. Nondecalcified ground section. Unstained. The length of the white bar is 1 mm.

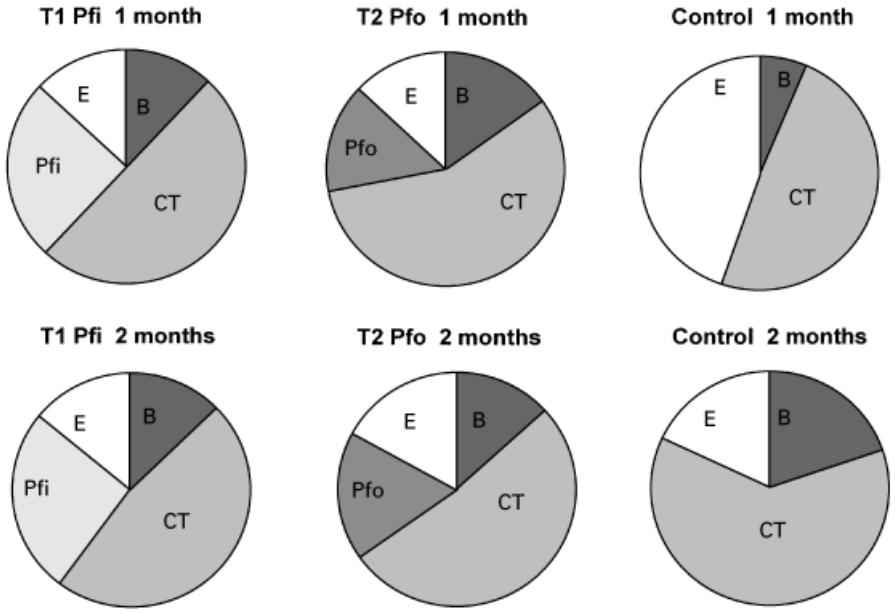

Fig. 10. Bone volume (B), connective tissue volume (CT), empty space (E) and filler material Polyfibre® (Pfi) and Polyfoam® (Pfo) in per cent of total volume available under the dome of control (C) and test groups (T1, T2) after 1 and 2 months.

foam®, consistait en un matériau de remplissage PLA spongieux. Dans chaque groupe il y avait huit lapins. Chez les lapins tests un lambeau a été élevé, découvrant le crâne. Un dôme PLA hémisphérique a été rempli de Polyfibre ® ou de Polyfoam® et de sang périphérique, et attaché au crâne. Huit lapins avec les mêmes dômes seulement remplis de sang ont servi de contrôles. Les lapins ont été euthanasiés à un ou deux mois. Des mesures histomorphométriques du volume tissulaire total, de la hauteur et du volume d'os régénérés ont été faites sur coupes non-décalcifiées sous un microscope optique. Après un mois, le volume total de remplissage atteignait 87% (de 82 à 91%) dans le groupe fibre dont 25% (23 à 27) de fibres, 87% (85-95) dans le groupe mousse dont15 % (15-16) de mousse et 55% (16-100) dans les contrôles. Le volume d'os minéralisé était de 12 % (7-15) dans le groupe fibre, 15% (12-18) dans le mousse et 6% (1-11) dans les dômes contrôles. La hauteur osseuse atteignait 48% (27-79) dans le groupe fibre, 37% (31-58) dans le mousse et 45% (14-67) dans le contrôle. Après deux mois le volume tissulaire atteignait 86 % (85-87) dont 26% (22-29) de fibres, le volume osseux 13% (7-21) et la hauteur osseuse 56 % (42-78) dans le groupe Poyfibre®. Dans le groupe Polyfoam® 83% (55-99) dont 18% (15-19) de mousse, 13% (7-24) et 49% (29-74). Dans les dômes contrôles le volume tissulaire était de 82% (35-100), le volume osseux de 20% (9-27) et la hauteur osseuse 86% (60-100). Les matériaux Polyfibre® et Polyfoam® étaient très bien intégrés. Aucun effet secondaire n'a été trouvé dans les tissus avoisinants. Une apposition osseuse directe a été observée sur le matériau. Les matériaux Polyfibre® et Polyfoam® ont un effet positif sur la formation tissulaire et osseuse initiale mais génaient l'augmentation du volume tissulaire, la hauteur et le volume osseux à deux mois comparé aux contrôles. Les matériaux Polyfibre® et Polyfoam® ne provoquent aucune réaction négative dans les tissus avoisinants et permettent une angiogenèse importante.

Zusammenfassung

Der Effekt von bioresorbierbaren Fasern (Polyfibre®) und bioresorbierbarem Schaum (Polyfoam®) auf die Bildung von neuem Knochen
Eine experimentelle Studie am Kaninchenschädel über einen kurzen Zeitraum
Es war das Ziel der Untersuchung, zwei bioresorbierbare Füllmaterialien aus Poly-Milchsäure (PLA) in einem Modell für die gesteuerte Knochenregeneration (GBR) zu untersuchen. Das erste war Polyfibre®, ein faserartiges PLA Füllmaterial. Polyfoam®, das zweite getestete Material bestand aus einem schwammartigen PLA Füllmaterial. Jede Gruppe bestand aus 8 Kaninchen. Bei den Testkaninchen wurde ein Lappen präpariert und die Kalvaria dargestellt. Eine halbkugelförmige PLA-Kuppel wurde mit Polyfibre® oder Polyfoam® Material und peripherem Blut gefüllt und auf der Kalvaria befestigt. Acht Kaninchen mit denselben Kuppeln, nur gefüllt mit peripherem Blut, dienten als Kontrolle. Die Kaninchen wurden nach 1 und 2 Monaten geopfert. In nicht entkalkten Schnitten wurden unter dem Lichtmikroskop histomorphometrische Messungen des totalen Volumens des regenerierten Gewebes, der Knochenhöhe und des Knochenvolumens durchgeführt. Nach 1 Monat erreichte das totale Füllvolumen 87% (Bandbreite 82-91) bei der Fasergruppe, einschliesslich 25% (23-27) Fasern, 87% (85-95) bei der Schaumgruppe, einschliesslich 15% (15-16) Schaum und 55% (16-100) bei der Kontrollgruppe. Das Volumen des mineralisierten Knochens betrug 12% (7-15) in der Fasergruppe, 15% (12-18) in der Schaumgruppe und 6 % (1-11) in den Kontrollkuppeln. Die Knochenhöhe erreichte 48% (27-79) in der Fasergruppe, 37% (31-58) in der Schaumgruppe und 45% (14-67) in der Kontrollgruppe. Nach 2 Monaten erreichte das Gewebevolumen 86% (85-87) einschliesslich 26% (22-29) Fasern, das Knochenvolumen erreichte 13% (7-21) und die Knochenhöhe erreichte 56% (42-78) in der Polyfibre® Gruppe. In der Polyfoam® Gruppe bertugen die Werte 83% (55-99) einschliesslich 18% (15-19) Schaum, 13% (7-24) und 49% (29-74). Bei den Kontrollkuppeln betrug das Gewebevolumen 82% (35-100), das Knochenvolumen 20% (9-27) und die Knochenhöhe 86% (60-100). Das Polyfibre® und Polyfoam® Material war ausgezeichnet

integriert. In den umgebenden Geweben wurden keine Nebenwirkungen beobachtet. Am Material konnte direkte Knochenauflagerung gesehen werden. Es wird die Schlussfolgerung gezogen, dass das Polyfibre® und Polyfoam® Material einen positiven Effekt auf die anfängliche Knochen- und Gewebebildung hatte. Aber es behinderte die Zunahme des Gewebevolumens, des Knochenvolumens und der Knochenhöhe nach 2 Monaten im Vergleich zu den Kontrollpräparaten. Das Polyfibre® und Polyfoam Material löste in den umgebenden Geweben keine Nebenreaktionen aus und ermöglichte eine ausgeprägte Angiogenese.

Resumen

La intención de este estudio fue evaluar dos materiales de relleno biorreabsorbible de ácido poliláctico (PLA) en un sistema de modelo de regeneración ósea guiada (GBR). El primer material probado fue Polyfibre®, un material de relleno-PLA fibroso. El segundo material probado, Polyfoam®, consistió en un material de relleno-PLA esponjoso. Había ocho conejos en cada grupo. En los conejos de prueba se levantó un colgajo descubriendo la calvaria. Se rellenó una cúpula hemiesférica de PLA con material de Polyfibre® o Polyfoam® y sangre periférica y se ancló a la calvaria. Ocho conejos con las mismas cúpulas, rellenas de sangre únicamente, sirvieron como controles. Los conejos se sacrificaron al mes y a los dos meses. Se llevaron a cabo mediciones histomorfométricas del volumen de tejido total regenerado, altura de hueso, y volumen de hueso en secciones descalcificadas bajo microscopía óptica. Al mes el volumen total de relleno alcanzó el 87% (rango 82-91) en el grupo de fibras, incluyendo 25% (23-27) de fibras, 85% (85-95) en el grupo de esponjas incluyendo 15% (15-16) de esponjas y 55% (16-100) en los controles. El volumen de hueso mineralizado fue del 12% (7-15) en el grupo de fibras, 15% (12-18) en el grupo de esponjas y 6% (1-11) en las cúpulas de control. La altura del hueso alcanzó el 48% (27-79) en el grupo de fibras, 37% (31-58) en el grupo de esponjas y 45% (14-67) en el grupo de control. A los dos meses el volumen de tejido alcanzó el 86% (85-87) incluyendo 26% (22-29) de fibras, el volumen óseo 13% (7-21) y la altura ósea alcanzó el 56% (42-78) en el grupo de Polyfibre®. En el grupo Polyfoam® 83% (55-99) incluyendo 18% (15-19) de esponjas, 13% (7-24) y 49% (29-74). En las cúpulas de control el volumen de tejido fue del 82% (35-100), volumen óseo 20% (9-27) y altura ósea 86% (60-100). El material de Polyfibre® y Polyfoam® se integraron excelentemente. No se encontraron reacciones adversas en los tejidos circundantes. Se observó aposición directa de hueso sobre el material. En conclusión: El material de Polyfibre® y de Polyfoam® tuvieron un efecto positivo en la formación inicial de hueso y de tejido pero fue un estorbo para el incremento de volumen tisular, volumen óseo o altura ósea a los dos meses en comparación con los especímenes de control. El material de Polyfibre® y de Polyfoam® no provocaron ninguna reacción adversa en los tejidos circundantes y permitieron una extensa angiogénesis.

要旨

本研究は、ＧＢＲのモデル系において、生体吸収性ポリ乳酸（ＰＬＡ）の２つのフィラー材料を評価した。第１は線維性ＰＬＡフィラー材料 **Polyfibre®**、第２はスポンジ性ＰＬＡフィラー材料 **Polyfoam®**であった。各々に８羽の家兎を割り当てた。試験群ではフラップを挙上して頭蓋冠を露出させて、半球状のＰＬＡ製ドームを **Polyfibre®** または **Polyfoam®** と末梢血で満たし、頭蓋冠に固定した。対照群の８羽の家兎では同じドームを血液のみで満たした。家兎は１ヶ月または２ヶ月で屠殺した。光学顕微鏡下で非脱灰切片を用いて組織形態計測を行い、再生した総組織量、骨高径と骨量を調べた。１ヶ月後にドーム内にできた総組織量は、**Fibre** 群では８７％で（８２－９１の領域）、そのうち２５％（２３－２７）が **fiber** 材料、**Foam** 群では８７％（８５－９５）で、そのうち１５％（１５－１６）が **foam** 材料、対照群では総組織量は５５％（１６－１００）であった。ドーム内の石灰化骨量は **Fibre** 群１２％（７－１５）、**Foam** 群１５％（１２－１８）、対照群６％（１－１１）であった。骨高径は **Fibre** 群４８％（２７－７９）、**Foam** 群３７％（３１－５８）、対照群４５％（１４－６７）であった。２ヶ月後 **Polyfibre®**群では総組織量は、２６％（２２－２９）の **fibre** を含む８６％（８５－８７）、骨量は１３％（７－２１）、骨高径は５６％（４２－７８）であった。**Polyfoam®** 群では１８％（１５－１９）の **foam** 材料を含む８３％（５５－９９）、骨量１３％（７－２４）、骨高径４９％（２９－７４）であった。対照群のドームは総組織量８２％（３５－１００）、骨量２０％（９－２７）、骨高径８６％（６０－１００）であった。**Polyfibre®** と **Polyfoam®** の材料はすぐれた骨性統合を達成していた。周囲組織に副作用は認められなかった。材料上に直接の骨添加が認められた。結論として、**Polyfibre®** と **Polyfoam®** の材料は、骨と組織の初期形成には効果を及ぼしたが、２ヶ月後には対照群に比べて、組織量、骨量あるいは骨高径の増加は認められなかった。**Polyfibre®** と **Polyfoam®** の材料は、周囲組織に副作用を惹起することはなく、広範囲の血管形成が起こった。

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