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CASE REPORT

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The clinical application of a new synthetic bone grafting material in oral and maxillofacial surgery

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A novel bone formation material based on hydroxyapatite-xerogel is presented. With the use of the innovative sol-gel technology this material is produced in the low-temperature range by the addition of silicon dioxide; in its structure it mimics to a great extent the natural bone matrix. This results in high osteoconductivity and an osteoprotective effect as well as in complete biodegradation corresponding to bone formation in the course of natural bone remodelling. Two case reports are presented.

Key words: maxillofacial surgery, synthetic bone grafting, hydroxyapafite-xerogel material

INTRODUCTION

As a result of alveolar bone destruction, profound parodontopathies often lead, to various degrees, to a loosening of teeth, which are then in need of treatment. In addition, bone defects frequently develop in the course of operative treatment of jaw cysts of varying genesis. If large in size, such cysts require bone replacement. Furthermore, atrophic processes following the loss of teeth are often accompanied by a loss of bone in the area of the alveolar process. A prosthetic and/or implant treatment often requires augmenting bone replacement. Usually the lost bone is replaced in the course of the therapeutic procedure, which may be during periodontal surgery or immediately after cystectomy. In implantology, however, use is often made of two-time procedures (delayed or secondary implantation). First the bone is augmented with replacement material and then the implant is made after approximately three months.

At present bone transplantation with autologous material is still the standard procedure. This procedure is advantageous in that it promotes bone healing. It also excludes allergic reactions and the transmission of viruses and prions, which might be caused by replacement materials of animal origin. However, the disadvantage of autologous bone grafts is that they require a second surgical intervention for bone removal, which may result in complications as well as in aesthetic and functional disorders. For this reason it seems appropriate to look for an alternative therapy that can be used instead of autologous bone transplantation, in other words for a synthetic bone formation material. Ideally, bone replacement materials are mounted in the defect through contact osteogenesis of the ingrowing bone, without being incorporated in the physiological bone reformation process ("bone remodelling"). In most cases they are degraded in part only, with resorptive-inflammatory processes being predominant. More

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often than not considerable residues remain in the tissue and replace the bone that was lost in the defect. Bone formation materials, however, promote the formation of new bone and participate in osseous remodelling. They are degraded in analogy with bone regeneration and are completely used up after the defect has been reossified. This means that, on principle, they are superior to bone replacement materials. Bone formation materials have osteoconductive properties so that autologous osteoblasts, collagen fibres and capillaries can migrate into the defect. This requires that interconnecting pores with diameters ranging from 3 to 100 μm and which comply with the natural collagen type I matrix in the bone be present in the biomaterial. This protein matrix carries the inorganic constituents of human bone, thus being a potential bone formation material. However, since its primary stability is inadequate, it is especially unsuitable for large bone defects. Synthetic products with a matrix structure that is similar to bone are the obvious choice. By charging bone formation materials with osteoblastic stem cells immediately before they are introduced in the defect, it is not possible to achieve accelerated reossification, because the transplanted osteoblasts do not survive as long as necessary to ensure their vascular supply [3].

CHARACTERISTIC FEATURES OF NANOBONE®

The innovative bone formation material has been approved as a medical product since January 2005 under the trade name of NanoBone® (ARTOSS GmbH Rostock). Its production is based on the sol-gel procedure [1], for which the sintering process usually required for ceramics at temperatures in excess of 1200°C is not applicable. The crystal size of the synthetic hydroxyapatite contained in NanoBone® is in the nanometre range. It is administered into an SiO_2 sol in powdered form and is distributed homogeneously. In the gel transition phase a nanoporous matrix developing via SiO_2 bonds connects the loosely packed hydroxyapatite crystals. The solvent escapes during the drying phase at a maximum temperature of 700°C; for this reason pores form within the micrometre size range. This results in a highly porous granulate with a porosity degree of approx. 60%. In addition, the surface that is wetted by body fluid *in vivo* is greatly increased. The interconnecting pores that are systematically generated through the formation of gel and during the drying process and whose sizes range from several nanometres to the higher micrometre size range reproduce to a considerable extent the inorganic bone structure, with the result that excellent osteoconductive properties are achieved [1].

CASE REPORTS

Case 1

A 54-year-old patient suffered from a residual cyst in his lower jaw in region 43–47. Owing to the extent of the cyst, as shown on the X-ray image and during the operation (Fig. 1a, b), it had to be filled with bone in order to accelerate the reossification process and to prevent any potential spontaneous fracture in the postoperative healing phase. Figure 1c shows the surgical site after application of NanoBone®. Before the defect was filled, the biomaterial, which was available as granulate, was thoroughly mixed with the patient's blood, which had been obtained from the surgical area through an injection syringe (if more blood is required, it can also be obtained through venous puncture). Any excessive blood should be removed, since otherwise there would be a supernatant of clotted blood, which would impede the application of NanoBone®. In addition, Figure 1c shows the high capability of NanoBone® to remain fixed in place in the defect. Figure 1d shows the radiological results one month after the operation. Contrast-inducing residues of NanoBone® can be detected centrally in the defect region. As expected, the defect reduction detected by the radiograph is still small at this point. A clinical and radiological follow-up will be made.

Case 2

This case presents a 37-year-old patient suffering from a profound parodontopathy in region 37. Figure 2a shows the clinical findings, while the extent of bone destruction reveals itself completely in the X-ray image (Fig. 2b) and the surgical site (Fig. 2c). Bone filling is indicated, because the stability of the pier tooth 37 is threatened. After being mixed thoroughly with the patient's blood, NanoBone® was applied into the periodontal defect (Fig. 2d). Since the latter is surrounded by bone in part only, the excellent capability of the biomaterial to remain fixed in place becomes particularly evident in this case. After the mucoperiosteal flap had been returned, the wound was closed without any gaps, using a non-absorbable suture material (Fig. 2e). A radiological check performed one month after the

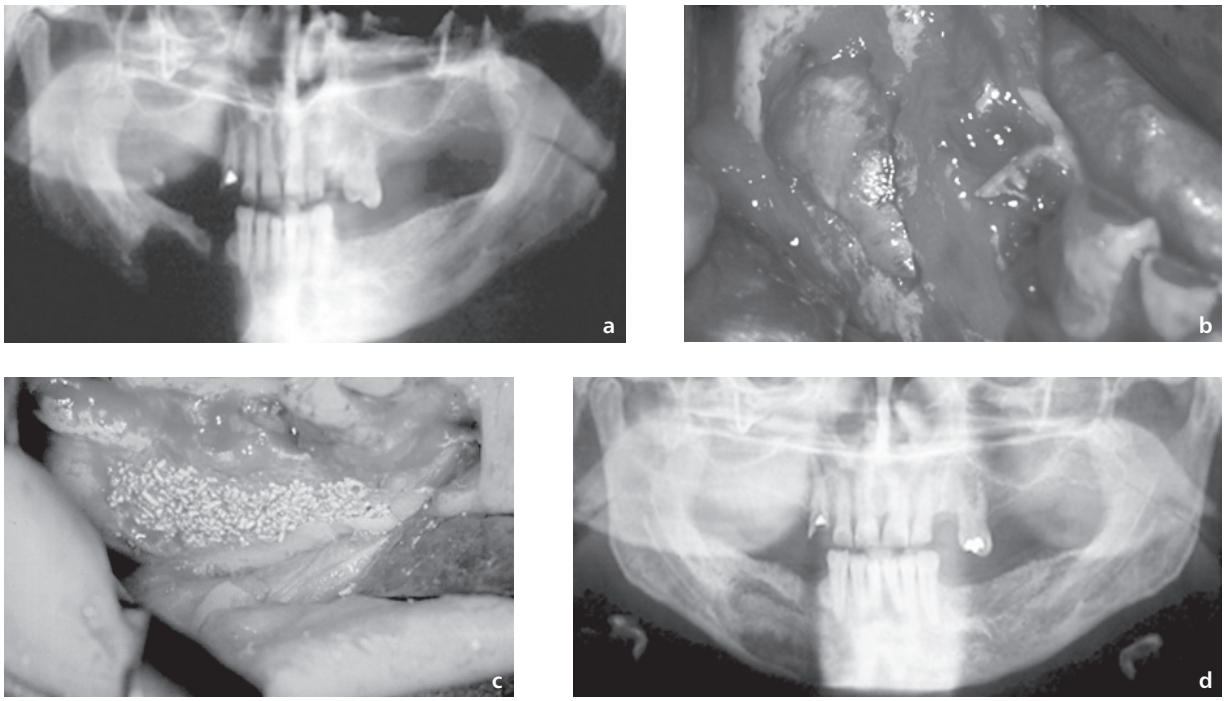

Figure 1. Large residual cyst in the lower jaw in region 43–47: **a.** Preoperative orthopantomography representing the rarefaction of the bone; **b.** Intraoperative site prior to cyst removal; **c.** State after cystectomy and application of NanoBone®; **d.** Orthopantomography one month after the operation.

operation showed a minor bone apposition in addition to contrast-inducing residual biomaterial. The final result will be revealed in the follow-up.

CONCLUDING REMARKS

Conventional bone replacement materials based on hydroxyapatite or beta-tricalcium phosphate and produced in a sintering process at temperatures of more than 1200°C have a high density and a low porosity [4, 6]. Their pores are exclusively within the micrometre and millimetre size ranges, and there are no nanopores. Since, moreover, the burning process induces pore ruptures, the interconnecting character of the pores of any size whatsoever is lost to a great extent. This production procedure reduces the osteoconductivity of bone replacement materials, while at the same time rendering their biodegradation more difficult. For this reason, bioceramics that are produced in the conventional manner are degraded only very slowly [8, 9] and, in most cases, incompletely; often resorptive-inflammatory reactions, which in turn impede the reossification process, can still be detected after many months [7]. Since their biodegradation is unsatisfactory, they just comply with the characteristic features of a bone replacement material.

Bone formation materials that are produced from protein-free bovine spongiosa have an optimum biological behaviour [5, 10]. Since they are produced in the low-temperature range, the natural structure and porosity of the bone are preserved to a considerable degree. However, the large-scale reprocessing procedures that are necessary for deproteinisation and sterilisation result in a devitalised bone matrix, which does not provide any advantages as compared with a synthetically produced matrix of similar structure. Just such a product is NanoBone®, which is also produced in the low-temperature range. NanoBone® was tested for its clinical usefulness in comprehensive short-term and long-term animal experiments on the mandible of miniature pigs [2]. In these tests NanoBone® showed a high osteoconductivity and a biodegradation behaviour corresponding to the formation of new bone. In addition, NanoBone® has a distinct osteoprotective effect in that it supports bone regeneration with a lasting effect, as opposed to the conventional sintered ceramics that are made of hydroxyapatite or beta-tricalcium phosphate. In other words, NanoBone® is to be classified as a bone formation material. An additional benefit of NanoBone® is its plasticity after it has been mixed with

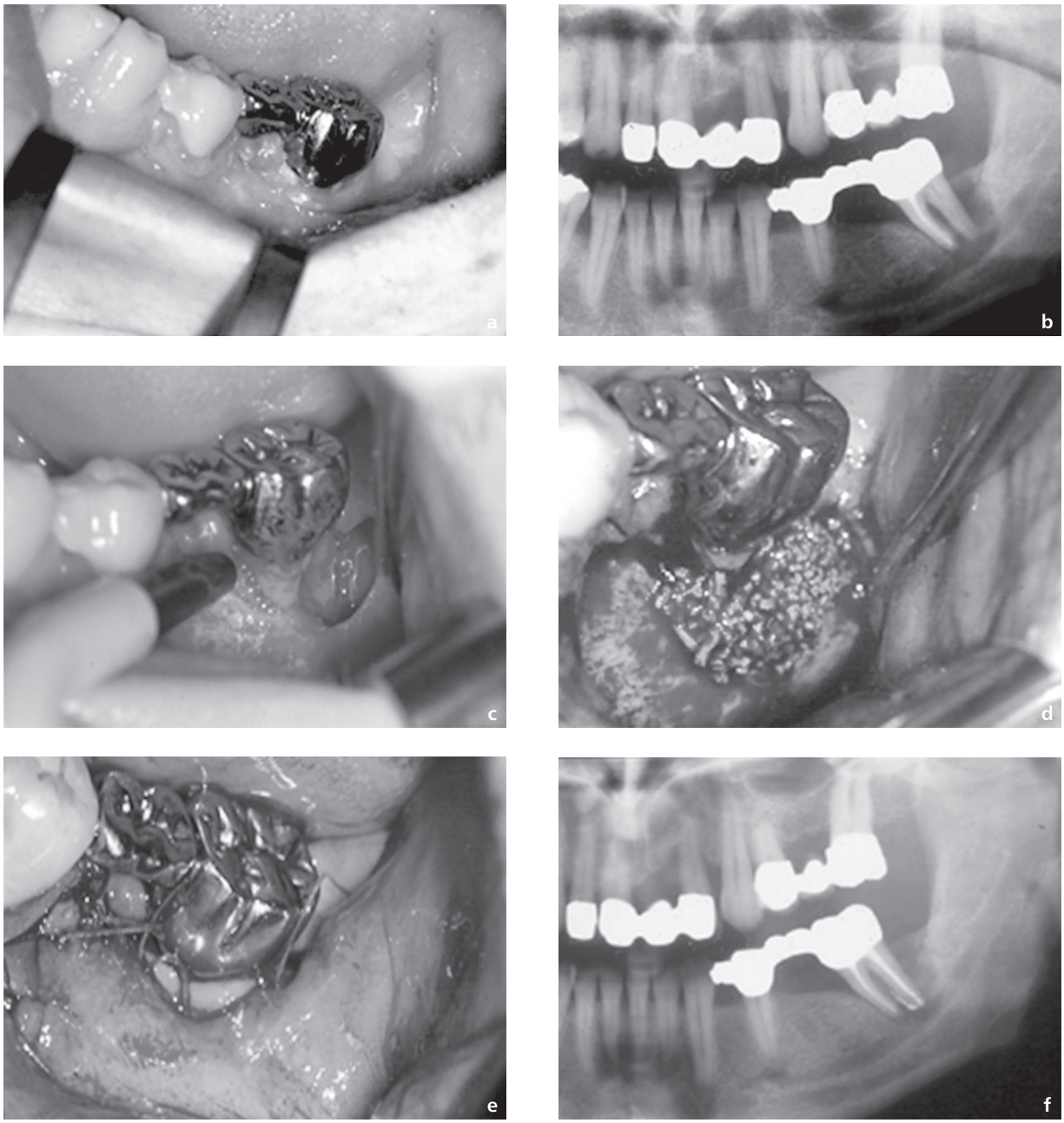

Figure 2. Profound parodontopathy, region 37, with alveolar bone destruction: **a.**, **b.** Preoperative clinical and radiological periodontal findings, region 37; **c.**, **d.** Surgical site prior and subsequent to the application of NanoBone®; **e.** State after closing of the wound without any gaps; **f.** Radiological results one month after the operation.

autologous blood. As a result, it can be handled easily during the operation and its ability to remain fixed in place is ensured. Since its launch we have treated 20 patients with this novel bone formation material at our clinic. In all of these patients it settled without any complication. None of the patients showed any postoperative inflammatory reaction, nor did they lose any of the applied NanoBone®.

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