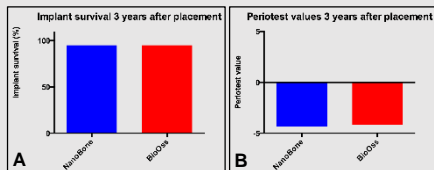


# Synthetic bone substitute material compared to xenogenic material for bone tissue regeneration: histological, histomorphometrical and clinical results (two years follow-up) from a split- mouth study in humans

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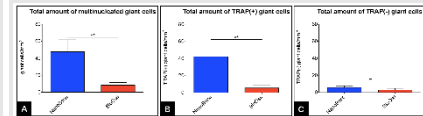
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**Figure 1.** In total 50 implants were placed in the augmented upper molar region. The distribution between implants placed in BO- and NB-augmentations was 1:1. (A) From the 50 implants one implant of each group did not survive the 3-year follow-up period, resulting in a survival rate of 95.00 % in both groups. (B) The mean Periosteal values were comparable between the two groups (BO: -4.16; NB: -4.36). None of the implants showed signs of peri-implant osteolysis or a marginal bone loss higher than 10% of the implant length.

**Introduction**  
 To prevent patients from an additional surgical site, bone substitute materials are common alternatives to autologous bone for augmentation of severely atrophic alveolar bone. The tissue reaction to bone substitute materials in the human organism depends on material characteristics, such as origin, composition or processing. Previously, the analysis of the cellular reaction of patients with head and neck cancer to NanoBone® (NB, Artoss, Rostock, Germany), a synthetic and Bio-Oss® (BO, Geistlich Biomaterials, Wolhusen, Schweiz) a xenogenic bone substitute material showed a significantly higher vascularization and significantly higher induction of tartrate-resistant acid phosphatase-positive (TRAP-positive) multinucleated giant cells in the NB-group. No significant difference was observed in the extent of new bone formation between both groups, while in the NB-group significantly more connective tissue and significantly less bone substitute material was present.<sup>1</sup>

In the present study, the same materials together with same investigation procedures were applied, in order to assess the tissue reaction of the above mentioned bone substitute materials in a healthy patient collective.



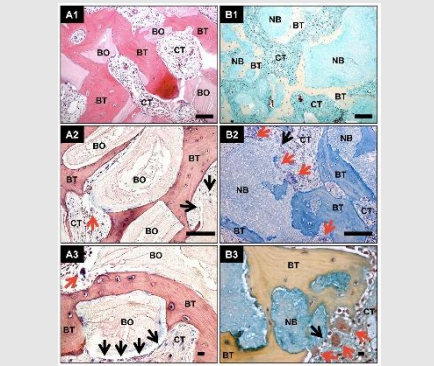
**Figure 2.** Histomorphometrical analysis of the amount of multinucleated giant cells. (A) The histomorphometrical analysis of the total amount of multinucleated giant cells showed a significantly higher amount in the Nanobone® group (\*\*). (B) The histomorphometrical analysis of the total amount of TRAP(+) giant cells in the Nanobone® group was significantly higher when compared to the total amount of TRAP (+) giant cells of the Bio-Oss® group (\*\*). (C) The histomorphometrical analysis of the total amount of TRAP(-) giant cells in the Bio-Oss® and Nanobone® group, showed a significantly higher amount in the Nanobone® group (\*).

A split-mouth sinus augmentation trial was performed to analyze the capacity of NB and BO concerning new bone formation within the augmented region together with clinical stability of the implants inserted within the augmentation regions. Six months after augmentation (by means of a lateral external sinus lift) cylindrical bone biopsies were extracted for histological and histomorphometrical investigation. The cellular reaction, a potential inflammatory response and the ratio of newly formed bone, connective tissue and remaining bone substitute material were evaluated. Further, the amount of multinucleated giant cells and the vascularization within the implantation bed was evaluated. Implants placed in the augmented regions were analyzed clinically (Perio-test value, Plaque Control Record, Gingiva Bleeding Index, gingival recessions and putride secretion) and radiology (peri-implant bone loss) two years after placement, to determine an influence of the cellular reactions on the clinical performance of the implants.

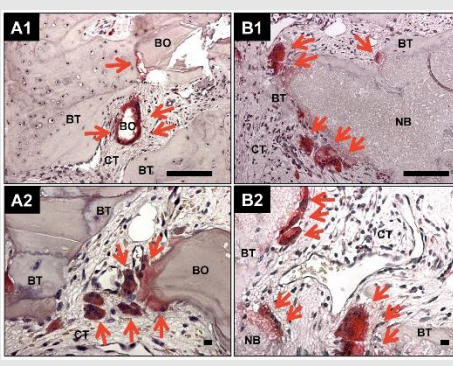
## Materials and Methods

## Results

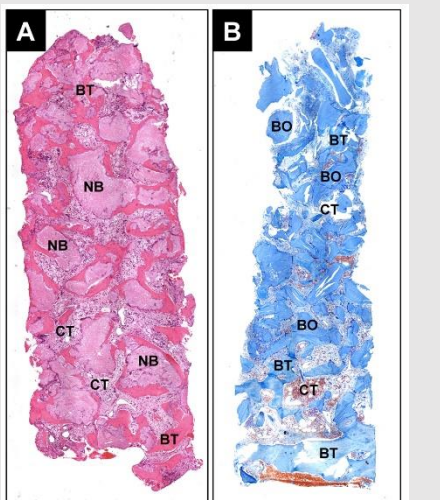
The synthetic NB-granules were well integrated in the peri-implant tissue and surrounded by newly formed bone. On the surface of remaining granules multinucleated giant cells were visibly. Also the xenogenic BO- granules were integrated in newly formed bone, which seemed to origin from active osteoblasts on the surface of the bone substitute granules. Histomorphometric analysis revealed significantly more vessels (NB: 28.69 ± 10.54 vessels/mm<sup>2</sup>; BO: 10.42 ± 3.74 vessels/mm<sup>2</sup>; \*\*\*p < 0.001, not graphed) and a significantly higher vessel fraction (NB: 2.13 ± 0.82 %; BO: 0.86 ± 0.33 %; \*\*p < 0.01, not graphed) in the synthetic study group. Further, significantly more multinucleated giant cells in the augmentation sides treated with NB could be detected. In contrast, the differences in fraction of connective tissue, amount of remaining bone substitute and newly formed bone did not show statistical significant differences. Both biomaterials led to a clinical successful implantation in all patients.



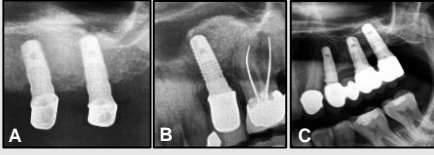
**Figure 3.** Evaluation of the biomaterials' integration. Within the Bio-Oss® group smaller particles are integrated within a network of newly formed bone tissue and well vascularized connective tissue. (A1-A3): (A1: H&E-staining, 100x magnification, scale bar = 100 µm; A2: Sirius Red staining, 200x magnification, scale bar = 10 µm; A3: Giemsa staining, 400x magnification, scale bar = 10 µm). In the Nanobone® group larger portions of the biomaterial remain, thus leading to a slightly decreased bone tissue formation, when compared to the Bio-Oss® group. (B1-B3) (B1: Movat Pentachrome staining, 100x magnification, scale bar = 100 µm; B2: Masson Goldner-staining, 200x magnification, scale bar = 10 µm; B3: Sirius Red staining , 400x magnification, scale bar = 10 µm).



**Figure 4.** Histochemical staining of tartrate-resistant acid phosphatase. This enzyme is mainly expressed by multinucleated giant cells (red arrows). When analyzing the distribution of multinucleated giant cells within both groups, the giant cells are more prominently expressed in the Nanobone® (B1-B2) group. In the Bio-Oss® group (A1-A2) fewer multinucleated giant cells can be found. (A1:TRAP staining, 200x magnification, scale bar 10 µm; A2:TRAP staining, 400x magnification, scale bar = 10 µm; B1: TRAP staining, 200x magnification, scale bar = 10 µm; B2: TRAP staining, 400x magnification, scale bar = 10 µm; red arrows: multinucleated giant cells).



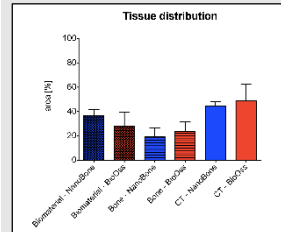
**Figure 5.** Total scans of the implantation area of both investigated biomaterials Nanobone® (A) and Bio-Oss® (B). groups (A: H&E-staining, 100x magnification; B: Azan-staining, 100x magnification).



**Figure 6.** Radiographic images at the three year follow-up investigation. (A) shows implants inserted in regio 25 and 26 restored with telescopic crowns for removable denture. (B) shows implant inserted in regio 26 restored with a single crown. (C) shows implants inserted in regio 24, 26 and 27 restored with a bridge construction. In all cases the peri-implant bone level was stable and no peri-implant osteolysis was detected.

## Conclusion

The results of this study highlight the different cellular reactions of synthetic and xenogenic bone substitute materials. The significant higher amount of multinucleated giant cells within the implantation bed of NB seems to not affect its biodegradation. Accordingly, it seems that the observed multinucleated giant cells within the implantation bed of NB have characteristics rather similar to foreign body giant cells than to osteoclasts. Results of a similar study, in a collective of patients with head and neck cancer revealed a significantly higher ratio of newly formed connective tissue, significantly more multinucleated giant cells and a significant lower ratio of remaining bone substitute material in biopsies of the synthetic biomaterial [1]. It can therefore be concluded that in head and neck cancer patients the synthetic bone substitute might undergo a more distinctive resorption without being related to new bone formation.



**Figure 7.** Histomorphometrical analysis of the tissue distribution in the implantation beds of the analyzed bone substitute materials, i.e., measurements of the contained connective tissue, new bone tissue and amount of biomaterial showed no significant differences.

1. Ghanaati S, Barbeck M, Lorenz J, Stuebinger S, Seitz O, Landes C et al. Synthetic bone substitute material comparable with xenogenic material for bone tissue regeneration in oral cancer patients: First and preliminary histological, histomorphometrical and clinical results. Ann Maxillofac Surg 2013; 3(2):126-38.