Histologic and radiographic investigations of bone defect obliteration with Bioactive Glass S54P3 and bone dust

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Introduction

Bone dust (BD) harvested during operation may be suitable as an autologous obliteration material for non-critical size defects. Bioactive glass (BA) can be an alternative. To treat non-critical size defects, BD and BA are commonly used for obliteration techniques. However, the optimal harvesting method and parameters for BD have not been examined. In this study, we analysed the osseoregenerative potential of both materials and the combination of both.

Experimental Methods

Thirteen female merino sheep (7 years old) underwent surgery on the frontal calvaria. During the surgical procedure four noncritical size defects (*1–4) (Fig. 3) measuring 10 mm in diameter were drilled into the calvaria. Each defect was drilled at a fixed speed of 15,000 rpm using a 7.0 mm Rosen burr and a commercial drilling machine. Defects were then filled as follows: defect *1 served as blank sample (BS) and remained unfilled; defect *2 was filled with BA (Fig. 2); defect *3 was filled with bone dust (Fig. 1) and defect *4 with a 1:1 mixture of BA and BD (BA/BD) (Fig. 1). The animals were sacrificed after 3 weeks. To evaluate bone regeneration, we used different methods.

For analysis of X-ray compact tissues, the defects were scanned by DVT after 3 weeks. The data referred to nine evaluated specimens in which the total defect volume of each defect was analysed. For sequential fluorochrome labeling (FSL), the dye Alizarin complexion was injected subcutaneously 2 weeks after operation. Fluorochromes are calcium-binding substances. FSL was used to visualize the fluorescence of new mineralised bone after 2 weeks of surgery. Measurement of bone mineral density (BMD) was assessed by peripheral quantitative computed tomography. It determines the physical density (mg/cm³) as mass/volume of each voxel. BMD was determined in 10 samples from each defect with the surrounding bone as a reference.

Statistical analyses were performed using SPSS 24.0 and Microsoft Excel 2010. Data are shown as means ± standard deviations. Differences with p values of less than 0.05 were considered statistically significant. (*** p <0.001, ** p < 0.01, * p <0.05)

Fig. 1: Bone dust collected with a bone dust collector

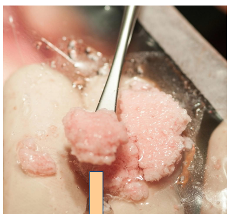
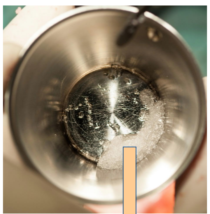


Fig. 2: Bioactive Glass S43P3



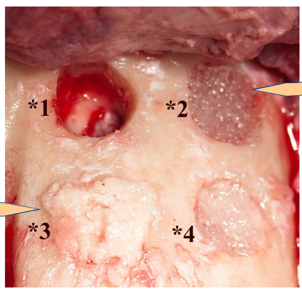


Fig. 3: Four defects in the calvaria

Results

All analyses showed quantitative and qualitative bone regeneration 3 weeks after operation. The BS defect showed a significantly less defect filling compared to all other (Fig. 4b). Analysis of the different gray values demonstrated centripetal bone growth, starting from the defect border to the center. The analysis of fluorochromes showed significantly more new mineralised bone in the defects filled with BD than compared to the blank sample and BA filled ones (Fig. 4a). Also in the BA/BD defect more new mineralised bone can be seen compared to the BA defect, but not significant. The defects filled with BA were the most filled and densest after 3 weeks (Fig. 4c). The defect filled with Bioactive Glass had the same amount of new mineralised bone as the reference one. Moreover, bone regeneration occurred from the surrounding bone and showed only a defect bridge in the BD-filled defects (alone and mixed with BA).

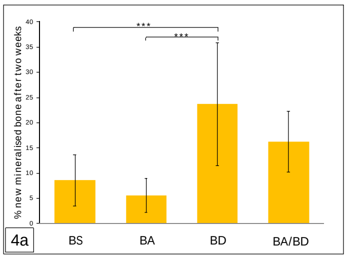
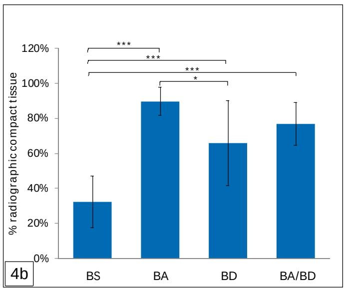


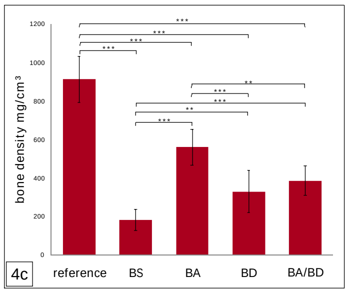
Fig. 4: Results of experimental methods in chronological order

Fig. 4a: Results of fluorochrome sequence labeling. Columns show mean percentages of new mineralisation after 2 weeks.

Fig. 4b: Results of DVT. Columns show mean percentages of radiographic compact tissues with standard deviations.

Fig. 4c: Results of bone density measurements. Columns show mean bone density (mg/cm³) with standard deviations.





Conclusion

BD and BA are suitable bone replacement materials for obliteration techniques because they completely fill the defects. Thus, BD harvested under standardised conditions provided a higher level of osteoreparation potential for the generation of woven bone and establishment of defect bridges. A mixture of both replacement materials combines benefits from both materials. Defects are completely filled, have a high density and osteoregeneration is faster due to vital bone cells in the obliteration material.

References

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