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ORIGINAL ARTICLE

Clinical, Radiographic and Pathohistological Outcomes of Hydroxyapatite (HAp) Ceramics and Dental Implants in Atrophic Posterior Maxilla

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Summary
Introduction. Implant based prosthodontic rehabilitation of patients with atrophic edentulous posterior maxilla has necessity in reinforcement of alveolar bone using different bone substitutes. It is important to evaluate late outcomes in integration of synthetic HAp as biomaterial in chemical composition close to main natural bone mineral component in elevated maxillary sinus floor and osseointegration of dental implants.
Aim of the study. To evaluate clinical and radiological outcomes of one stage maxillary sinus floor augmentation with synthetic HAp granules and dental implant insertion, mineralization degree of residual bone and augmented sinus part, morphological analysis of biopsies from HAp/ host tissue hybrid and residual alveolar bone was performed.
Materials and methods. One stage maxillary sinus floor elevation with synthetic HAp granules and 147 SEMADOS (BEGO) dental implant insertions in 70 patients were included in this study. Clinical and radiograph analyzes by dental X-rays, digital orthopantomogramms, quantitative radiodensitometry after 3 and 5 years was done. Trephine biopsies of residual alveolar bone and elevated part of maxillary sinus 6 months after implantation was done in 30 cases.
Results. During this period 6 implants (4.2%) were lost. We found the decrease of radiodensity in HAp augmentated maxillary sinus area and increase of radiodensity in the area of residual alveolar bone. In biopsies after 6 months biomaterial/host tissue hybrid consisted of small bone trabecules, fibrous tissue and granules of irregular shape without inflammatory cells. Slow degradation of HAp granules by activity of osteoclast like macrophages was observed.
Conclusions. Osseointegration was lost in 4.2% of inserted in augmented maxillary sinus implants. Radiodensitometry showed decrease of optical density in augmented sinus part and increase in residual alveolar bone. In biopsies of host tissue/biomaterial hybrid was bone newformation, connective tissue and biodegradation of HAp granules by osteoclast like cells.
Key words: atrophic posterior maxilla, synthetic hydroxyapatite, radiodensitometry, biopsy.

INTRODUCTION

Alveolar bone of the jaws is the primary support structure for teeth and after their lost for dental implants with unique continual and rapid remodelling subsequently the functional demands and loading in mastication. It is well recognized that tensional forces stimulate osteogenesis while compressive forces promote osteoclastic activity (16). Maxillary posterior edentulous region from expansion of the sinus after teeth loss and decrease of bone density presents unique challenging conditions in implant dentistry (9). Sinus floor elevation with bone or artificial materials increases availability of bone height, and jaw bone loading during prosthodontic phase of the reconstruction (2). Autogenous bone grafting recognized as gold standard among advantages has also disadvantages as extra surgery with possible morbidity of donor site, limited available volume, difficulties to foresee resorbtion and final outcome of bone grafting, especially in recipient site where active resorbtion of previous host bone occurred (15). Implant loss after one stage sinus auto bone grafting is near 20% (8). Calcium phosphate ceramics have proven to be one of the more successful high technology-based biomaterials that have developed within the past decades (6). HAp is the main natural inorganic compound of bone and essentially has affinity and biocompatibility to the bone tissue. It has superior properties for the stimulation of osteogenesis and bone bonding, both related to the specific interactions of surface with the extracellular fluids and cells, ionic exchanges, superficial molecular rearrangement and cellular activity (1). There are clinical, radiological and morphological methods for the assessment of grafting materials used as bone substitutes for maxillary sinus floor elevation. From the clinical point of view and also for the general assessment not just grafting material but a lot of local and general factors influence the survival of dental implants in host bone/ biomaterial hybrid and stability of implant-supported artificial teeth. Quantitative radiodensitometry was used for the evaluation of tissue density in healing mandibular fractures (17).

MATERIALS AND METHODS

The properties of synthesized powder and sintered ceramics were investigated by chemical compositions of high purity, X-ray diffraction, SEM, FT-IR methods. HAp powder was calcined at 800°C for 1 h, pressed in blocks and sintered for 1 h at 1150 - 1200°C. Granules were prepared by grinding the ceramic blocks. To evaluate up to 5 years late outcomes of one stage sinus floor elevation with synthetic HAp and 142 SEMADOS (BEGO) dental implant insertion in this study were included 68 patients with alveolar bone in posterior maxilla not less than 5 mm in height and more than 4 mm in width - Misch class SA2 – SA3. Clinical and radiographs analyzes by method of quantitative radiodensitometry (CADIA), in cases of 5 lost implants scanning electron microscopy (SEM), electron diffraction X-ray (EDX) chemical microanalysis methods were used. The subject evaluated by quantitative radiodensitometry was the optical density, which is opposite to the traditional interpretation of X-rays where more dark till black corresponds to less dense tissue and white corresponds to density of implants or abnormal high mineralization of bone. As a more logical decision for clinical framework, we chose the conversion of units of absolute optical density to percentage rate assuming the density of titanium implants 100% and the density of oral cavity as 0%; there were the radiodensity of alveolar bone and augmented sinus floor between these marginal values. We have used dental periapical X-rays, panorex and paraxial computer tomography scans to analyze optical density in the residual alveolar bone and elevated maxillary sinus part. The digital image was processed by Leica Quantimet (Leica Corporation, Cambridge, UK) image-processing system using a computer equipped with Image-Pro Plus system software for image analysis. SPSS 7.5 program statistical analysis was used. On 24 patients after one stage sinus floor elevation with synthetic HAp granules and SEMADOS dental implant insertion at second stage surgery average after 6 months 2 mm diameter trepan biopsy of biomaterial/host tissue hybrid and alveolar bone was done. Samples were fixed in 10% neutral formalin and decalcinated. Slices were stained with hematoxyline/eozine and according Masson trichrom, evaluated in light microscope.

RESULTS

There were no acute suppurative inflammations from oral and also nasal-maxillary sides. One implant was lost on the second stage surgery caused by soft alveolar bone and dubious primary stability. Another 5 implants were lost after 2 – 4 years after loading may be from overloading; poor oral hygiene resulted in periimplantitis. Another 136 implants showed no complaints from patient side, clinical stability. On control X-rays was evident osseointegration, increase of residual alveolar bone density, decrease of density in elevated part of maxillary sinus floor.

Figure1a,1b

Radiodensitometry of the elevated sinus floor area and residual alveolar ridge shows 98 % of optical density in the sinus lifts area after implant placement. 82% of sinus lift bone hybrid after uncovering on average 6 months of the dental implants, 76 % after 3 years of initial loading of the dental implants and 65 % after 5 years of the implant loading. However, residual alveolar crest area exhibits 55 % of optical density after the implant and sinus floor elevation with HAp granules, 64 % of sinus host tissue/HAp hybrid after uncovering of the dental implants, 78% after 3 years and 70 % after 5 years of the implant loading.

Figure 2

Our histological study showed decrease of number and activity of osteocytes in atrophic alveolar residual bone, osteoporosis. 6 months after sinus floor elevation with synthetic HAp granules there was no active inflammation, HAp/tissue hybrid consisted of bone trabecules, partially mineralized bone, fibrous and loose connective tissue. Biodegradation of HAp granules by active osteoclast like macrophages was evident.

Figure 3a, 3b

We observed more pronounced inflammation reaction with the xenomaterial bovine Tutodent (Tutodent Gmbh) implantation in the maxillary sinus after 6 months.

Various chemical composition biomaterials after implantation in the maxillary sinus shows different biodegradation mechanisms Ca2CO3 (Algipore, Friadent) – chemical/ dissolution.

Figure 4, 5

There are only some publications on human histological cases on retrieved dental implants from augmented maxillary sinus floor. 2,5 years after sinus floor elevation with combination of 25% freeze dried demineralised bone and 75% OsteoGraft/N700 (CeraMed Dental, Lakewood) and two implant insertion dense lamellar bone was present in direct contact with the threaded HAp coated part of retrieved implant. The particles of inorganic bovine bone (OsteoGraft/N 700) were not completely resorbed; no osteoclasts were present and the graft particles did not seem to be undergoing any type of resorbtion or remodelling (14).

Our clinical case, when we explanted Semados (Bego) implant at the removal caused by periimplantitis in the residual alveolar bone but with stable integration in HAp grafted sinus floor area, in three years demonstrated direct mechanical integration of HAp/tissue hybrid to the titanium implant without any intermediary tissue and sharp border between these different chemical compositions with no chemical interference.

Figure 5a, 5b

DISCUSSION

There are reports on lost 2.5 – 18 % of dental implants inserted in augmented maxillary sinus with different auto and allomaterials (11, 13). Failures in osseointegration of dental implants depends from kind of used bone substitutes. In database including 6 913 implants placed in 2 046 patients in follow-up time ranging from 12 to 75 months implant survival was 87.7% with grafts of 100% autogenous bone, 94.88% in combination of autobone with different bone substitutes and 95.98%

when bone substitutes were used alone (4).
Radiographs are more commonly used methods for the evaluation on alveolar bone/dental implant relations as well in grafted maxillary sinus part. Unfortunately, almost all grafting materials have a tendency to decrease their initial size over the time. Long term average height as estimated at Sinus Grafting Consensus Conference (1996) was 2.1±0.3 mm when freeze-dried bone allograft was used and respectively 1.8±0.4 mm in cases of iliac crest bone and 0.9±0.3 mm when using alloplasts. Our data on sinus floor elevation with pure synthetic HAp confirmed high stability of bioceramic/host tissue hybrid with no lost of height of elevated sinus portion and average loss of 0.7±0.3 mm of crestal bone portion during long period of observation.
The main interest is the morphology of host tissue/ biomaterial hybrid in sinus floor augmented with HAp or another inorganic bone substitutes that are mostly investigated in experiment. The histological and histometrical evaluation of porous Hap as a grafting material for sinus lift done on monkeys gave a solid confirmation of good Hap biocompatibility, its biodegradation and replacement by mineralized bone with high values of direct bone-to-bioceramic contact. Significant difference was obtained in bone-to-implant contact between residual bone and augmented area, but also at 45.8% to 68.7% of dental implant surface had direct contact to mineralized bone; respectively this contact in residual bone area was 60.9% to 92.3% (4). Histological evaluation of 3 different grafting materials for sinus lifting procedure bases on 8 cases after 6 months indicated that demineralised freeze-dried bone powder resorbs earlier than deproteinized bovine bone granules and porous HAp [12]. Histological evaluation of 3 different grafting materials for sinus lifting procedure bases on 8 cases after 6 months indicated that demineralised freeze-dried bone powder resorbs earlier than deproteinized bovine bone granules and porous HAp (12). Histomorphometric study after one year grafting of sinus floor in 21 patients using autogenous particulated bone from the mandibular ramus, bovine HAp and mixture of both showed no differences between the 3 groups, indicating that autogenous bone graft can be substituted with bovine HAp to 80% or 100% (5).
An essential property of bone substitutes is their possibility to be integrated into the natural bone remodelling, which starts with osteoclastic activity followed by osteogenous cell activity. Osteoclastic cells of different origin cultured on calcium phosphate biomaterials produced clear difference in the shape and the depth of resorbtion lacunae. Degradation measurements revealed a significant increase of P and Ca release in the presence of osteoclasts (10). Formation of osteoclast-like cells was more pronounced on HAp surface as on tricalcium phosphate (TCP) and was explained with high dissolution rate of TCP and high Ca concentration in the osteoclast interface and environment (3).

CONCLUSIONS

1) Radiodensitometry in long term evaluation shows increase of optical density in residual alveolar bone and decrease of optical density in augmented with synthetic HAp granules maxillary sinus floor.
2) Biopsies from residual alveolar bone and augmented maxillary sinus floor demonstrate HAp/host tissue hybrid remodelling by activity of osteoclast like cells and bone newformation, slow biodegradation of Hap granules.
3) Our experience as well as previous publications confirms that synthetic porous HAp granules used as artificial material for maxillary sinus floor elevation in one stage with insertion of titanium non –coated dental implants in cases of residual alveolar bone height not less than 5 mm may be the method of choice for implant based prosthetic reconstruction of the atrophic posterior maxilla.

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Conflict of interest: None

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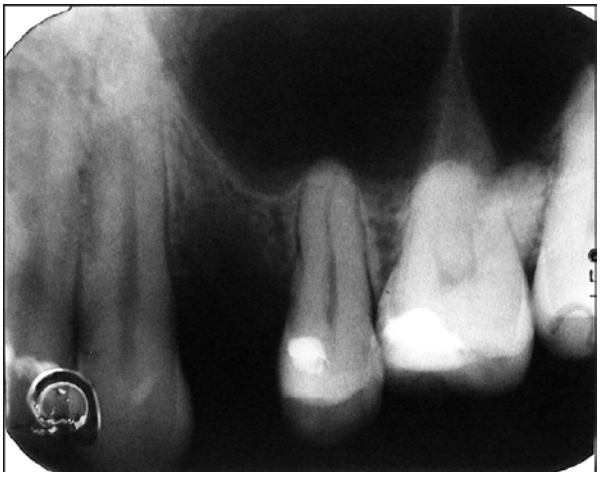
1A



1B

Fig. 1a, 1b. Dental X-rays of patient A.J. with loss of upper premolar with soft, radiolucent alveolar bone before and 2 years after sinus floor elevation with HAp granules 0.2 – 0.4 mm, porosity 40%

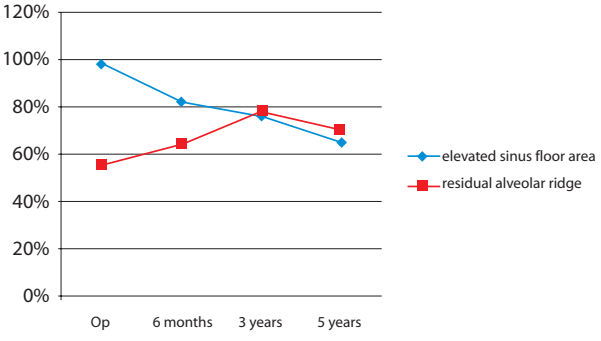
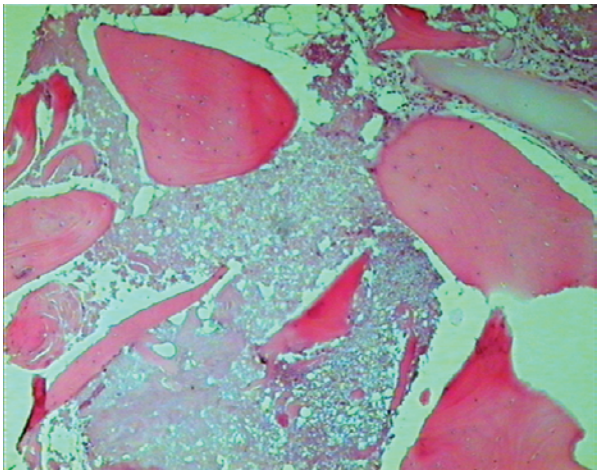


Fig. 2. Results of radiodensitometry of residual alveolar bone and augmented with HAp granules maxillary sinus part immediately after implantation, 6 months, 3 and 5 years after



A x 60

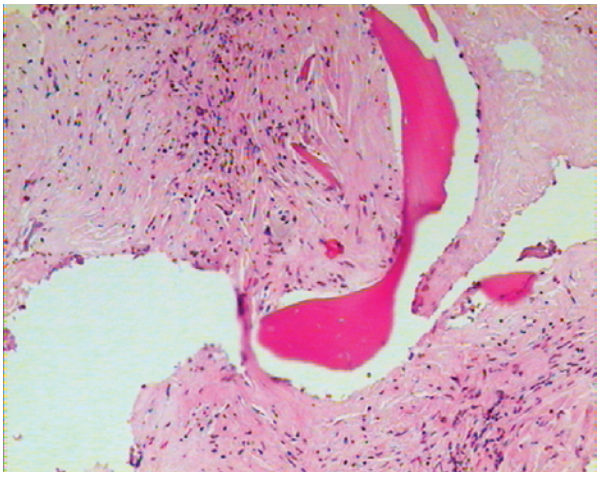
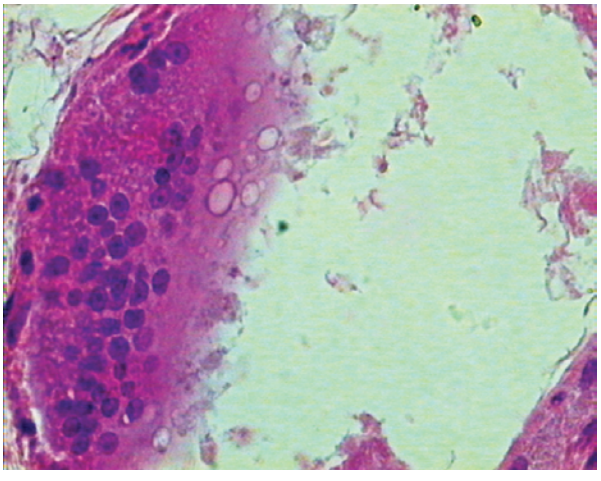


Fig. 4. Maxillary sinus augmented part with Tutodent after 6 months osteogenesis, osteomielofibrosis, no inflammation Hem-eoz x 60B



B x 200

Fig. 3. Microphotogramms of biopsies from residual alveolar bone and augmented with HAp granules sinus after 6 months

A) Biomaterial/host tissue hybrid consisted of small bone trabecules, osteoid, fibrous tissue and granules of irregular shape without inflammatory cells;

B) Degradation of Hap granule by activity of osteoclast like macrophage

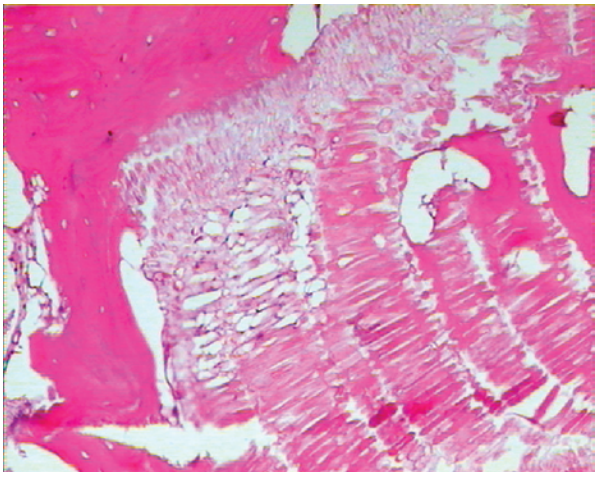


Fig. 5 Algipore, material dissolution without cell activity/Hem-eoz x 60

Fig. 4. Retrieved partially osseointegrated Semados (Bego) titanium dental implant:

A) crossed section of the implant shows bone/HAp hybrid in the threads of implant part from augmented sinus and no osseointegration in crestal part involved in periimplantitis;

B) SEM micrography of titanium dental implant integrated after maxillary sinus floor elevation by synthetic HAp granules (porosity 35 – 40%) 3 years ago