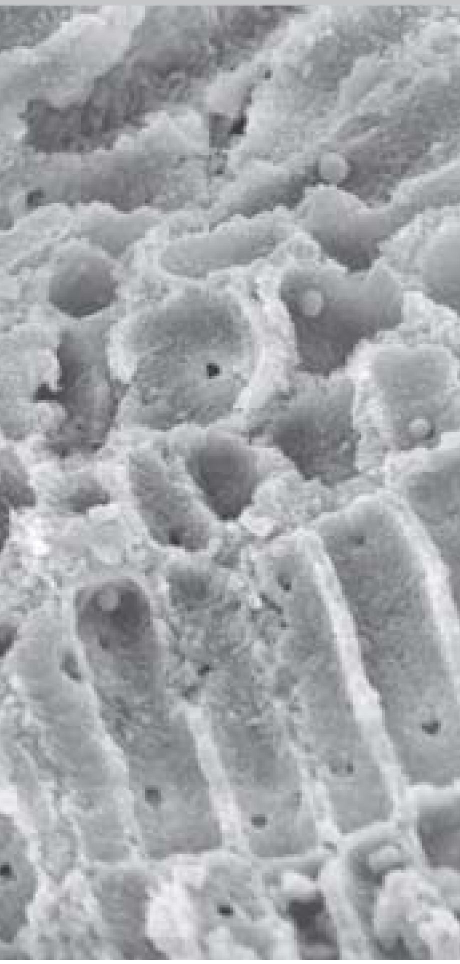


from science for the practice

Bone generation with Frios Algipore

| Licia Manzon | Giovanni Fratto | Antonio Scarano | Vittoria Perrotti | Marco Degidi | Adriano Piattelli | Giovanna Iezzi

BONE REPLACEMENT OR BONE REGENERATION?

Autogenous bone is considered the “gold standard” among augmentation materials. The best augmentation material is autogenous bone without a doubt, but often there is none available or only in an insufficient quantity. In such cases, a xenogeneic, allogeneic or alloplastic material is required as a substitute to fill the defect. Bone augmentation with inorganic alloplastic granulates is today’s international clinical standard. These materials fill the defect and are then more or less completely converted into autogenous, newly formed bone. This type of bone regeneration is especially important with a view to the osseointegration of implants. If the augmented material is not completely resorbed, it remains permanently as non-endogenous material. No new bone forms at the implant interface. No osseointegration takes place there in the strict sense.

Generally, all materials on the market lead to bone replacement, but only a few to actual bone regeneration. Where does the difference lie between bone replacement and bone regeneration? As the word suggests, in bone replacement the bone is replaced or the necessary volume filled. This does not necessarily mean that new bone forms here, i.e. the bone is regenerated.

An ideal bone augmentation material leads to bone regeneration, because it is continuously resorbed and simultaneously replaced by autogenous bone.

This assumes that the process of material degradation (resorption) and the formation of new bone proceeds at a similar speed, i.e. almost synchronous.

In this case there is no volume loss of the augmentation material, on the one hand, and the material remains in the organism as a foreign body for no longer than is necessary, on the other.

(from left to right)
Professor Licia Manzon, MD, DDS
liciamanzon@fastwebnet
Prof. Giovanni Fratto, MD, DDS
Dr Antonio Scarano, DDS, MD
ascarano@unich.it
Dr Vittoria Perrottti, DDS, PhD
v.perrotti@unich.it
Dr Marco Degidi, MD, DDS
info@degidi.it
Prof. Adriano Piattelli, MD, DDS
apiattelli@unich.it
Dr Giovanna Iezzi, DDS, PhD
gio.iezzi@unich.it

Dental Schools Sapienza Rome and Chieti Universities, Italy

FRIOS ALGIPORE – PURE NATURE

Xenogeneic augmentation materials should be of a similar or identical basic chemical structure to the bone material (hydroxyapatite). Besides the chemical composition, the physical / morphological structure of the material represents an essential prerequisite for bone regeneration. The resorption of bone augmentation materials is mainly determined by their physicochemical and structural-morphological characteristics. In this regard, the porosity, especially the size and distribution of pores, combined with the pore geometry, plays a significant role. Most commercially available preparations based on hydroxyapatite are purely synthetic or of animal origin. Although these hydroxyapatite products correspond chemically with the natural bone, they are not degraded sufficiently. They are practically "non-resorbable". So these materials can only be considered as bone replacement in the sense described above.

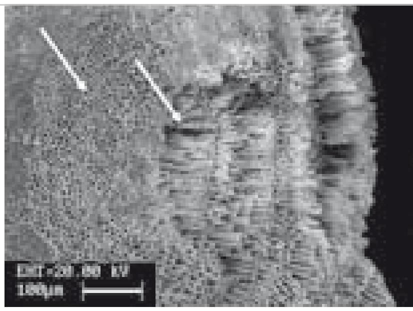
Frios Algipore is of plant origin, i.e. a phycogenic material, and is harvested from coral weed (Corallina officinalis). This type of red algae has a mineral, microporous framework (Fig. 1). All organic constituents are removed by heating in the manufacturing process. What remains is highly porous, biological calcium carbonate (tab. 1). It has fine pores within the algae structure (from the algae skeleton) which are all connected together via micrometer sized openings (Fig. 2). This is termed ideal interconnecting porosity. This structure has a very high specific surface area. Every pore is bounded by a fluorohydroxyapatite layer.

The Frios Algipore granulate has a microarchitecture and chemical composition comparable to bone. The porous structure serves as a scaffold for tissue regeneration and contributes to migration of cells into the pores. The size of the granules allows penetration of blood vessels (vascularization) into the phycogenic augmentation material. That is an important property to allow cell growth and later the formation of bone tissue and structures. These processes and the chemical structure of Frios Algipore also ultimately form the basis for resorption of the material which accompanies bone growth.

These processes can only be explained in detail through histological studies. The histological and histomorphometric results are presented from a study on an animal model and on the basis of human material.

Granulate	
Size	*0.3–2 mm*
Specific surface area	*32–50 m^2/g*
Pores	
Width or diameter	*5–10 μm*
Length	*50–100 μm*
Volume	*0.93 cm^3/g*
Perforation connecting the pores	*1–3 μm*
Hydroxyapatite crystals	*25–35 nm*

Table 1_The structure of Frios Algipore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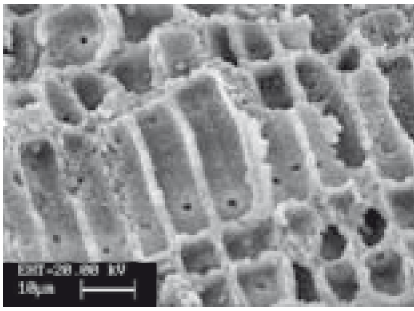
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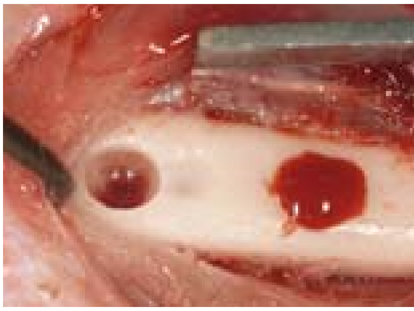
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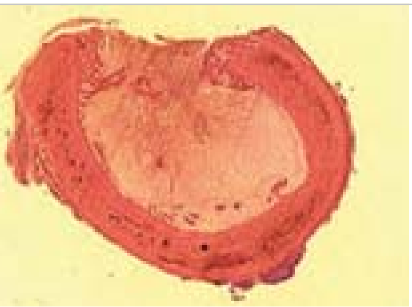
1_The pores within the particles of Frios Algipore (magnification 236 x) with regularly structured septums (arrows).

2_The individual pores – diameter 10 μm, length 30 μm, connection opening diameter 1 μm (magnification 2190 x)

3_Two defects of 7 mm diameter were formed on each shin bone.

4_At first glance, the resected specimen is little different from the filled bone defects.



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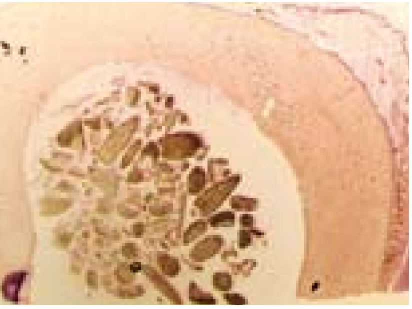

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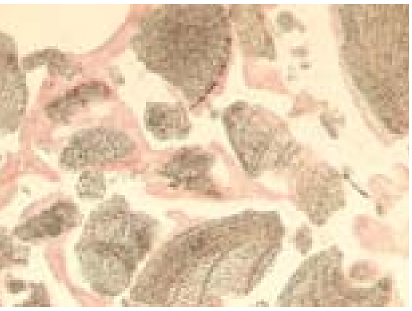

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FOUR WEEKS AFTER INCORPORATION

In an animal study approved by the ethics commission (Chieti-Pescara University, Italy), two cavities of seven millimeter diameter were prepared in the shin bone of six rabbits (Fig. 3). The twelve test cavities were filled with Frios Algipore. Twelve cavities received no filling and served as the control group. All defects were covered with a resorbable collagen membrane. After four weeks, histological preparation of the bones (Fig. 4) was carried out on the bones for the histological and histomorphological evaluation (tab. 2) according to a standardized protocol.
In the cavities without filling (control group) newly formed bone was only found in the marginal regions (Fig. 5). This constituted around 30 percent. The large marrow spaces (around 68 percent) are noticeable. In contrast, the test cavities filled with Frios Algipore were completely filled in with a large quantity of newly formed bone (Fig. 6). What is remarkable, however, is not only the bone formation between the particles, but also in the pores of Frios Algipore (Fig. 7). There were no gaps between the biomaterial and the bone and also no infiltration of inflammatory cells. In some areas lacunae arising from resorption were apparent (Fig. 8). The result can be interpreted that parts of the Frios Algipore had been completely resorbed and replaced by newly formed bone. Osteoblasts secreted the osteoid matrix directly on the particles of Frios Algipore.

SIX MONTHS AFTER INCORPORATION

Ten patients were selected for the human study according to a previously defined study protocol. In eight patients the maxillary sinus was unilaterally augmented with Frios Algipore, in two patients bilaterally. After a regeneration time of six months, 23 Xive implants were inserted.
Within this insertion process it was possible to obtain 23 bone nuclei. Preparation for the histological and histomorphological investigation was performed according to a standardized protocol. Most of the Frios Algipore particles were surrounded

	Cavity with Frios Algipore	Control group
Proportion of:		
Newly formed bone	*31.1 % ± 1.9 %*	*30.2 % ± 2.2 %*
Marrow space	*34.7 % ± 4.3 %*	*68.7 % ± 4.1 %*
Frios Algipore	*33.4 % ± 2.8 %*	
Newly formed bone within the Algipore particles	*35.3 % ± 4.8 %*	
Contact between new bone and Algipore	*71.2 % ± 9.8 %*	

Table 2_Histomorphometric results of the animal study

5_Control group – new bone only in the marginal regions of the defect and large marrow spaces (magnification 12 x).
6_The particles of Frios Algipore are even identifiable at low magnification (12 x).
7_Almost all particles are surrounded by newly formed bone and bone at various stages of development (magnification 100 x)
8_For some particles, resorption has started after just four weeks, identifiable from the regions filled with bone (magnification 200 x).

by mineralized tissue. The particles formed an osteoconductive scaffold (Fig. 9). As observed in animal bone, there were bridges of newly formed bone between the particles (Fig. 10). There was also newly formed bone within the pores (Fig. 11). The resorption of the particles and replacement by new bone had started. Lamellar bone and Havers' systems were found in direct contact with Frios Algipore. The histological features in and around the particles showed all the signs of an active regeneration process of the bone: vascularization, collagen fibrils, osteoblasts secreting the matrix, etc..
The bone invasion was probably especially intensive in the particle fragments. Soft tissue encapsulates particles without bone contact. In regions with resorption of Frios Algipore there were all the signs of osteoclastic activities (Fig. 12).

SUMMARY OF RESULTS

The results from animal and human bone show comparable processes and results in terms of osteoconductive properties and resorption of Frios Algipore. Both studies confirm that Frios Algipore is a material with high biocompatibility and osteoconductivity. There was no infiltration of inflammatory cells or foreign body reactions. All particles showed almost complete osseointegration. Most were connected together with bridges of newly formed bone fragments. There were clear signs of resorption of Algipore particles in the period of observation. However, most of the material still existed. It is known from the literature that residues of the material are still to be found after two years. The structure of the granules and the pore size allows migration of bone cells and thus the growth of new bone in the pores of the partially resorbed particles. Neovascularization was also observed in the samples. Frios Algipore can be used successfully for sinus augmentation and bone regeneration. Taking the limitations of these two studies into account, the results shown here are supported by the literature. ■

Literature on request from the authors

The results of these two studies were presented as a poster at AO 2010 (Orlando).

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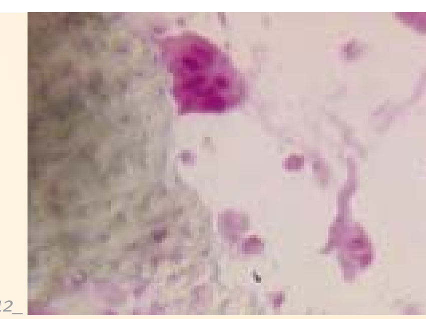

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	Sinus augmentation (after 6 weeks)
Proportion of:	
Newly formed bone	*35.2 % ± 3.6 %*
Frios Algipore	*37.1 % ± 3.8 %*
Marrow space	*35.6 % ± 2.3 %*

Table 3_Histomorphometric results of the human study

9_Human preparation with newly formed bone and particles of Frios Algipore six weeks post-op (magnification 12 x).
10_Newly formed bone spreads out into the pores (magnification 100 x).
11_Bone apposition around the particles and in the pores (magnification 100 x).
12_An osteoclast in contact with the Algipore particle: lacuna-type recesses as typical signs for active resorption (magnification 100 x).