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Review Article

Multidisciplinary Utilization of Surgiplaster: Chemical, Physical, Biological Properties and Mechanisms of Action and Resorption

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Introduction

In a recent article by Thomas and Puleo (2008) [1] it is said: "Calcium sulphate occupies a unique position in the universe of regeneration materials. It has an older and longer history of clinical use than other materials and is widely recognized as a well-tolerated material with applications in bone regeneration. Despite these positive characteristics it has never achieved great popularity, although there has recently been a revival of interest.

Some articles have highlighted peculiar characteristics; Payne, et al. (1996) [2] evaluated the ability of cultured gingival fibroblasts to migrate, in response to a stimulus, on various materials with barrier function: polylactic acid, polyglycolic acid, PTFE and calcium sulphate. The cells were able to migrate further on the sulphate surface and the fibroblasts maintained their morphology and their functionality. The authors suggested that this feature could be used in surgical sites, where primary closure could not be achieved.

A study by Strocchi, et al. [3] created bone defects in rabbit tibias by filling them with sulfate granules (Surgiplaster) or autologous bone. Microvascular density (MVD) was increased at sulphate-treated sites, suggesting a positive effect on angiogenesis. This increase in vascularity may be the reason for the positive biological effect of the material.

Walsh, et al. (2003) [4] filled critical defects in rabbit thighs with sulfate granules and used immunohistochemistry to identify various growth factors in situ.

They detected an elevated concentration of morphogenetic protein (BMP) -2 and (BMP) -7, of transforming factor -β (TGF-β) and of platelet-derived growth factors (PDGF).

These important studies have brought back interest in calcium sulphate on the part of clinicians and researchers. In reality, the clinical experience on the multidisciplinary use of this material by many allows today to evaluate very interesting and stimulants.

There are many reasons justifying the interest in calcium sulphate. Peltier (1961) [5] exalts its ductility and underlines how it has proved to be a valid bone substitute.

Ricci, et al. (2000) [6] studied and defined the biological mechanisms by which calcium sulfate is replaced by bone.

Histological studies, Piattelli (2003) [7], have shown that among biomaterials, in terms of biodegradability, the primacy belongs to the Fisiograft, followed immediately by the Surgiplaster.

Keywords: Biomaterials, Biocompatible Materials; Bone Regeneration; Bone Augmentation; Calcium Sulfate; Clinical Applications

Histomorphometric Analysis of The Biomaterials Examined

BIOMATERIALS	% NEW BONE	% MEDULLARY SPACES	% RESIDUAL BIOMATERIAL
NATIVE BONE	40,1	40	18
POLYLACTIC AND POLYGLICOLIC ACID	33	59	3
CALCIUM SULFATE	38	45	13

Chemical, Physical and Biological Properties of Surgiplaster

Calcium sulfate is commonly known as plaster of Paris.

Plaster of Paris has been used for centuries as a finishing material in construction, with or without the addition of additives such as fibers, hemp fiber, sawdust. Its first use in medical practice was the treatment of fractures in which it was used to immobilize the injured limb as a cast or was incorporated into bandages and splints.

Its value as a bone substitute was discovered quite by accident.

Calcium sulfate is a crystalline salt that can exist in various stages of hydration, based on the degree to which water is associated with the crystalline structure. Gypsum is a natural mineral that consists of the dihydrated form of calcium sulfate ($CaSO_4$ x $2H_20$). The least hydrated form is Calcium sulfate hemihydrate ($CaSO_4$ x ½ H_20), also known as Plaster of Paris, whose main characteristic is solidification when mixed with water (re-hydration), forming the dihydrate, and releasing heat in the process.

Calcination :

$CaSO_4$ x $2H_20$+heat à $CaSO_4$ x $1/2H_20+3/2H_20$

Re-Hydration :

$CaSo_4$ x $1/2H_20+3/2H_20$à$CaSO_4$ x $2H_20$+ heat

The calcination process can be carried out under steam pressure in an autoclave, at 120 to 130 ˚C, or in free air, at 110 to 120 ˚C. Both methods produce hemihydrate, but with different crystalline properties. Heating under steam pressure produces alpha-hemihydrate, characterized by crystals with a prismatic shape. Heating in open air produces beta-hemihydrate, which contains irregularly shaped crystals.

"The best biomaterial the safest is the one that is reabsorbed and does not interfere with physiological healing"

The SURGIPLASTER is unique, it has been renewed, it has regained the dimension that belongs to it, for its history and for the continuous evolution generated by an extensive clinical experience and continuous experimentation. among the different areas of use of the Surgiplaster, the immediate post-extraction regeneration is the most suggestive, the most useful, the most predictable, the most used by clinicians.

From the first formulation (Surgical) with the "stratification" technique, which was based on the assumption of the need for a barrier action of the sulphate, to hinder the competitiveness of non-osteogenic cells in the defect, Sottosanti (1993) [8] (Pecora 1997) [9], we moved on to the formulation in granules.

Many researchers have found that this new formulation, while presenting the advantage of a progressive and slower solubilization percentage, did not fully respond to the needs of an osteoconductive stimulus protracted over time and modulated on the needs and times regenerative.

It should be noted that **SURGIPLASTER** is a calcium sulphate-based material, but its formulation, granulometry, physical-chemical characteristics and, therefore, the mechanism of action and its influence on the various regenerative phases are Particular, Unique, Effective, Original and Predictable in the results.

SURGIPLASTER is available in 3 types: P30, G170 and Sinus, with physical-chemical characteristics, production processes and actions selective which can be spoken of generically, without revealing specific originalities.

In particular, the compaction technique, without pressure, the rapid aggregation of the granules, due to their shape, size, surface, allows an exceptional ductility of use in the various defects and in the different clinical situations.

These granules dramatically decreased the pain that often accompanied the compaction of cement and some types of granules in post-extraction defects.

The hypothesis is that the acidity produced in the first 48 hours of solubilization in organic liquids was too fast and massive and the pain was the consequence.

The compaction technique has also allowed the respect of the principle expressed by Mellonig (2004) [10] in his article "Geometrically guided osteoconduction", established the correlation between the size of the granules and the times of resorption and that the granulometry must be adequate to the size of the defect.

The granules of SURGIPLASTER GHIMAS have furrows, holes, with cavities which favor the differentiation and engraftment of the cells and condition their survival.

They also possess the following characteristics:

- 1-Induce greater localization of endogenous BMPs (bone morphological proteins)
- 2-They promote the differentiation of osteoprogenitor cells
- 3-They facilitate the application of the new bone matrix
- 4-They favor the process of Osteogenesis

Mechanism of action of surgiplaster

By what mechanisms can bone healing be improved using Calcium Sulphate?

How does the Surgiplaster work?

Three important questions:

1) how quickly does it heal?

2) how does it affect bone healing?

3) how does it react with body fluids?

The reabsorption of the Surgiplaster is conditioned by the size of the granules, their consistency and the local conditions of the defect.

The dissolution of the surgiplaster causes the precipitation of calcium phosphate (CaP). The mineral deposits observed with histology and with the scanning microscope are not of calcium sulphate, but of a calcium phosphate precipitate, which is formed as soon as the sulphate reacts with organic liquids.

Calcium Phosphate (Cap) Analysis

CaP precipitates form on the surface of the CS, about one day after incubation in SBF (Simulated Body Fluids). The pH drops to 6.5 as soon as dissolution/precipitate occurs. The CaP precipitate is released from the surface simultaneously with the dissolution of the underlying CS granule. Spectrographic analysis of CaP identifies it as carbonate apatite, similar to that observed in bone and dentin.

HOW DOES THE SURGIPLASTER WORK?

1-MECHANICAL mechanism

2-PHYSICAL-CHEMICAL mechanism

3-MOLECULAR mechanism

MECHANICAL - in the sense that it fills the space, preventing the formation of fibrous tissue, through a "selective blocking" phenomenon: the cells osteogenic cells are attracted to the defect, non-osteogenic cells are rejected. It is hypothesized that the phenomenon occurs through a system controlled by humoral factors.

PHYSICAL-CHEMICAL - the precipitate of apatite deposits, which form an osteoconductive SCAFFOLD, which supports newly formed vessels, facilitating bone growth.

MOLECULAR- with increased molecular stimulators of ANGIOGENESIS and bone formation.

(CaP)

In 1965, Radenz and Collings [11] filled induced bone defects in the mandibles of dogs with calcium sulphate. At two weeks X-rays revealed considerable resorption of the material. At three weeks, x-rays demonstrated considerable trabecular bone pattern. At twelve weeks, the trabecular bone pattern of the TEST sites was denser than the CONTROL sites, with equal amount of bone. Histological observation showed that, in the initial stage of healing, calcium sulfate allowed less epithelial invasion into the defect than in controls. Final healing at twelve weeks was similar, with more prominent bone design and improved level at the sulfate-filled sites. The authors were impressed by the extremely benign reaction of the fabrics towards the material. In conclusion, Radenz and Collings observed that the alveolar bone responded to the sulfate implant with the resorption of the material and its replacement with bone.

An article by Strocchi 2002 [3], reports that the increase in angiogenesis in rabbit tibias grafted with calcium sulfate "the presence of a greater number of blood vessels, in the sites treated with CS, could explain the excellent results, reported in the literature with the use of sulphate". An article by Walsh on CS granules grafted into defects created in the femoral condyles of sheep concludes that histological examination shows "increased immunostaining for bone morphogenetic protein-2 (BMP2), bone morphogenetic protein-7 (BMP-7), transferring growth factor beta (TGF beta) and platelet derived growth factor (PDGF), had been detected in the defects filled with CS granules"

Resorption

In vivo dissolution takes place with a hydrolytic mechanism through which, in contact with biological liquids, it releases calcium and sulphate ions. The former, combining with phosphate deposits, give rise to calcium phosphates, constituting the "aggregation nuclei", which support and stimulate bone growth.

Sulphates are degraded by the Krebs cycle and become carbon dioxide and water. The body's physiological control mechanisms dictate the timing of excretion through respiration, perspiration and urine, so that there is no increase in serum calcium level. (Ricci et al.2000) [6]. Countless histological checks confirm at six and nine months, in different clinical situations, the absolute and complete biodegradability of the material.

Clinical Applications

Calcium sulfate has been successfully used to treat periodontal disease, endodontic lesions, alveolar bone loss, and maxillary sinus augmentation [12,18]. One of the most studied and most used products, based on calcium sulphate, is the Surgiplaster (Ghimas, Casalecchio di Reno, Bologna, Italy).

Multidisciplinary use of SURGIPLASTER:

Oral Surgery

1- in post-extraction sockets or post-disinclusions (figure1-4)

2-in post cystectomy cavities

3-in post bone harvesting cavities

4-as hemostatic in cavity for mechanical and chemical ability

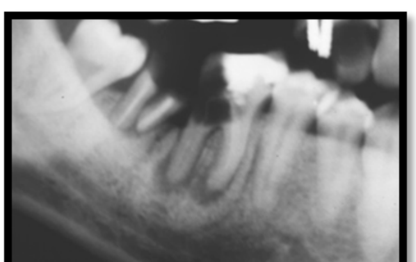

Figure 1: Pre-Extraction Residual Roots and Hopless Molar.

Figure 2: Post-Extraction.

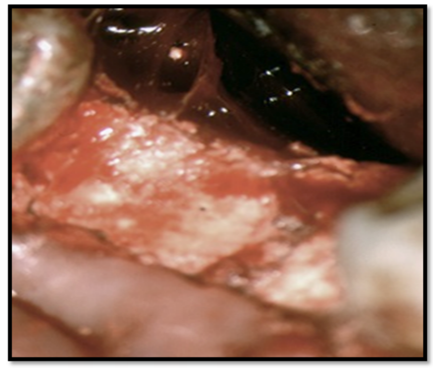

Figure 3: Preservation Socket with Rugiplaster.

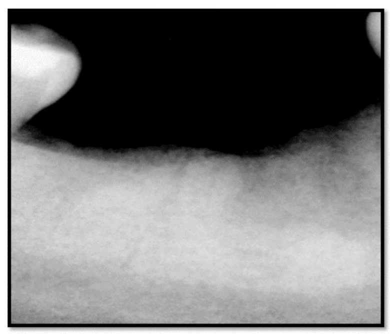

Figure 4: Healing After Socket Preservation with Surgiplaster.

ENDODONTICS

1-as a matrix on which to compress the filling material in the open apices and in the furcal and root perforations

2. in surgery as a hemostatic, in perforations of the sinus membrane, in large lesions, in bicortical lesions, in endo-perio lesions Pecora [19].

PERIODONTOLOGY

1-in the treatment of two-three wall lesions Farina [20]

2-in root covers Anson [21]

IMPLANTOLOGY

1- In implant insertion sites, as a biological stimulator

2-As graft material in crestal or lateral sinus floor elevation Andreana [22] (figure 5-7).

3-In bone dehiscences or fenestrations

4-In the crestal split

5-In peri-implantitis

6-Immediate implants (Pecora) [23,24]

7-Repair of an oro-antral communication, Doobrow [25]

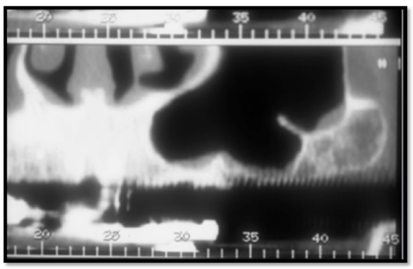

Figure 5: RX Pre Sinus Floor Elevation.

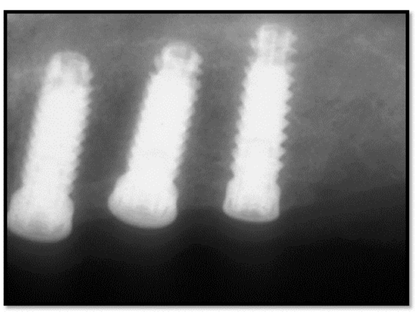

Figure 6: Post Insertion Implants In Maxillary Sinus.

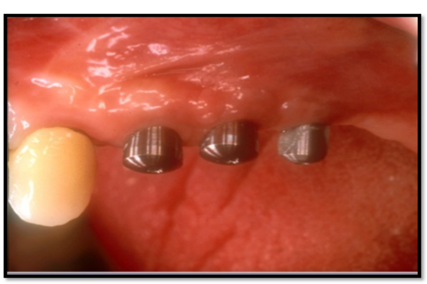

Figure 7: Tissue Healing Around Implants.

SINUS AUGMENTATION

The surgical protocol is generally shared by most operators.

The newly formulated SURGIPLASTER (Ghimas, Casalecchio di Reno, Bologna, Italy) has characteristics in line with research and with the needs of a breast graft material.

Sinus floor elevation surgery can interfere with sinus physiology by:

- inhibition of ciliary activity;
- change in the composition of the mucus;
- increased mucus secretion;
- compromised patency of the ostium: excessive lifting and particles of grafted material.

Important risk factors include:

1) the experience of the operator;
2) the sinus compliance of the patient.

By "compliance" we mean the ability to recover sinus homeostasis following a pathological stimulus.

In this way, SURGIPLASTER, thanks to the dimensions, the shape of the granules, the compacting technique, becomes ductile and easy to handle, thus allowing a better and more suitable use.

According to the concept expressed by Mellonig (2000) [10] of "geometrically dependent osteoconduction", numerous clinical experiences have developed which have supported and corroborated this intuition.

Ridge Preservation

The prevention of post-extraction resorption is a problem addressed by many authors. Various were the techniques and materials proposed in the latter years. The difficulty of finding valid evaluation parameters, added to a discrepancy of ideas and theories, has not allowed to propose a single and reliable operating protocol both for the quality and for the predictability of the results. However, from clinical experience and from research carried out by various groups, and in particular by the GIR, from articles published around the world, some important data can be extrapolated. Pecora [26],Guarnieri [27].

First = The materials used in post-extraction regenerative techniques must not interfere with normal healing processes.

Second = The healing of the soft tissues and bone must allow for an optimal insertion of the implants, respecting aesthetics and function.

Third = The post-extraction sites are potentially infected and the inserted materials must not create an environment conducive to bacterial growth.

Fourth = Technique and materials used must favor closure by secondary intention and the overlying soft tissues. This is because the primary closure would require, in most cases, a sliding of the flap with loss of attached gingiva.

Of all the materials used, SURGIPLASTER, based on calcium sulphate, has shown to possess the required characteristics.

The new Surgiplaster adapts, therefore, in an optimal way to the needs of the post-extraction site, improving the adaptability of the material, modulating the resorption times more correctly to the regenerative needs.

In cases of loss of one or more walls, the association with another material, the Fisiograft (polyglycolic polylactic acid) in the form of a gel, has been tested. As for the positioning technique, it is extremely simple and quick. The compound is formed by mixing this material with Surgiplaster P30 or G170, and acquires a hard elastic consistency which allows the insertion of the material in one go.

The healing of the site by secondary intention occurs with minimal dispersion of the material. In the first 3-4 days the oral fluids flow over the compound without altering the shape or consistency.

Regenerative techniques using Surgiplaster G 170 have undeniable advantages over other immediate post-extraction regeneration techniques

Products Cs Based Commercially Available

There are many products based on calcium sulphate that are introduced on the market, taking advantage of the history and bibliography of completely different situations. One issue is calcium sulphate, a different issue is a product based on calcium sulphate, without specifying the type. The commercial name is mentioned but neither the physical-chemical characteristic nor the production technique is described. This carelessness does not help those products that are the result of serious research, the fruit of discussed and verified protocols.

When we talk about calcium sulphate and discuss its physico-chemical properties, clinical characteristics and mechanisms of action, it is advisable to specify what type of sulphate we are talking about. The hemihydrate or dihydrate form, α- β crystallization, cement, granules, all these differences have an important determinism on the indications for use and on the results. Research results are improperly attributed to different forms and types of sulphate, this generates confusion and distrust in users because often, when the results do not meet expectations, the failure is attributed to calcium sulphate and not to the specific product. It therefore comes as no surprise that the results of the various researches are often different and even in opposition, because there are different animal models, different indications, different defects, different products based on Calcium Sulphate (Kelly, et al. 2003) [28].

Conclusions

There is no doubt that Calcium Sulphate, whatever its shape, consistency, application technique generally has a positive effect on bone defect healing. However, it is clear that the changes made to the material, in the composition physical-chemical, in the shape of the granules, in the consistency, have a positive effect on the action mechanisms and consequently on the results.

In the case of the Surgiplaster, each modification is the result of in vivo and in vitro research, the application of rigid operating protocols, and large and controlled clinical experience.

It is a fundamental error to consider calcium sulphate generically and not the individual products, which are considerably different in their formation and mechanisms of action (Kelly, et al. 2003) [28].

Colleagues, users of SURGIPLASTER, it is important to remember that "clinical success cannot be determined by experience, skill, choice, by the operator, of techniques and materials; the result must be conditioned and determined by clinical observations and statistics, checked and confirmed on animal models, which allow us to arrive at an operative technique, which is highly predictable and reproducible by most".

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