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Correction of Craniofacial Skeleton Contour Defects Using Bioactive Glass Particles

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ABSTRACT

Correction of craniofacial skeleton contour defects is better managed by using similar tissues; bones or bone substitutes. This has an advantage over using soft tissues to contour these deformities. This article aims to evaluate correction of craniofacial skeleton contour defects using Bioactive Glass particles. Seven patients were included. They complained of forehead deformities (traumatic in two patients and congenital in one), and maxillary deformities (post surgical in one patient and congenital in three patients). Bioactive Glass particles were applied sub-periosteal in all patients. Required contour was achieved in all patients. There was no post-operative complication and the contour was maintained. Application of Bioactive Glass particles to contour craniofacial skeletal deformity is an easy, safe, effective, and long-lasting procedure.

INTRODUCTION

Deformity of the craniofacial skeleton may be congenital, traumatic, post inflammatory, post surgical or post tumor resection. Apart from major skeletal deformities which necessitate advancement osteotomies, distraction osteogenesis or bone grafting, minor skeletal deformities like contour defects need simple procedures **[1]**. Many articles described how such simple procedures could contour the craniofacial skeleton **[1-12]**. These procedures involved the use of hydroxyapatite cement (Bone Source), **[3,9-12]** hydroxyapatite block, **[4]** hydroxylapatite granules, **[2,8]** carbonated calcium phosphate bone cement [Norian CRS (craniofacial repair system) or CCPP (carbonated calcium phosphate past], **[7]** high-density porous polyethylene implants, **[5,6]** or Bioactive Glass-Ceramic implants **[1]**.

Bioactive glass particles (NovaBone) have not been used before to contour the craniofacial skeleton but their efficacy as bone substitutes and their safety have been proven **[13]**. The advantages of Bioactive Glass particles over other biomaterials were discussed in literature **[14,15]**. This manuscript is to evaluate bioactive glass particles (NovaBone) in contouring the deficient or irregular craniofacial skeleton.

PATIENTS AND METHODS

Synthetic bioactive glass particles (NovaBone) consist of 45% silica dioxide, 45% sodium oxide, 5% calcium and 5% phosphate. The bioactivity begins when they are mixed with saline or blood **[16]**. Silicon-oxygen bonds are broken to release silicic acid, which condenses to form a negatively charged gel at the surface of the particles. This gel serves to hold the glass particles in a cohesive mass **[14]**. This helps easy manipulation during insetting, and prevents migration.

Seven patients were included in this study. Data of all patients are shown in Table (1).

Road traffic accidents were the cause of trauma in patients numbered 1 and 2 in Table (1). The congenital anomaly in the patient numbered 3 was congenital supraorbital hypertrophy and lateral forehead deficiency. This condition was named by Salyer as frontometaphyseal dysplasia **[17]**. Surgical-debridement for cutaneous mucor-mycosis in immuno-competent patient left the deformity in the patient numbered 4. She presented six years after complete cure of the condition to correct the deformity. Consultation of her dermatologist was performed before operating on her. It is rare for immunocompetent individuals to have mucormycosis but it does happen as mentioned by Losee et al. **[18]**. The congenital anomalies in the last three patients (numbered 5, 6 and 7 in Table 1) were complete prealveolar, alveolar, and post alveolar clefts. They had previous correction of lip and palate. They presented by anterior palatal fistulae, cleft alveolus and retro-displaced alae.

The pre-operative photos for the patients numbered 1, 2, 3 and 4 in Table (1) are shown in Figs. (1a, 2a, 3a & 4a).

All patients were photographed preoperatively and consents were taken to approve the use of bioactive glass particles (NovaBone). All patients received general anesthesia. Intravenous antibiotic was administered to all patients intra-operatively. The incisions were different according to case. They were through preexisting scars in the forehead in the patients numbered 1 and 2 in Table (1). The incision in the patient numbered 3 was coronal incision. The incision in the patient numbered 4 was a horizontal upper sulcus incision. In patients numbered 5, 6 and 7 in Table (1), the incisions were vertical upper sulcus incisions and gingivo-periosteal flaps were created for alveolo-plasty. The incision in the periosteum was created at a higher level than skin incision in the patients numbered 1 and 2. Sub-periosteal dissection was performed in all cases. The bioactive glass particles (NovaBone) were put in the created subperiosteal pockets in all patients. The bioactive glass particles (NovaBone) were mixed with saline solution before applied in the subperiosteal pocket. The shaved bone in the patient numbered 3 was reused as bone graft to contour the forehead in collaboration with the bioactive glass particles (NovaBone). In patients numbered 5, 6 and 7, the bioactive glass particles (NovaBone) were applied both in the created alveolar pockets and in the subperiosteal pocket of the parapyriform aperture maxillae. Briefs of all associated surgical interventions are shown in Table (1). The wounds were closed in two layers to insure adequate soft tissue coverage. The foreheads and maxillae were tapped for 3-4 days to prevent mobilization.

RESULTS

All patients recovered from anesthesia uneventfully. They received prophylactic post-operative broad-spectrum antibiotics. All wounds healed very well. Extrusion of few amounts of the bioactive glass particles (NovaBone) were noticed in patients numbered 4 and 5 in the first postoperative day but stopped spontaneously. There was no infection detected in any patient. All patients were photographed just postoperatively and at least two weeks later. All patients were followed up for at least two months. The patients numbered 1, 3 and 4 were followed up for one and half year. All associated surgeries were successful. The contouring was maintained and all patients were satisfied. Post-operative photos for patients numbered 1, 2, 3 and 4 are shown in Figs. (1b, 2b, 3b & 4b).

Table (1): Data of all patients.

Patient	Age	Sex	Cause	Deformity	Surgery
1	42 Y	M	Trauma	Saddle nose + mid-forehead depression	Costal cartilage for nasal dorsum + subperiosteal bioactive glass particles
2	37 Y	F	Trauma	Mid-forehead depression	Subperiosteal bioactive glass particles
3	19 Y	F	Congenital	Supraorbital hypertrophy and lateral forehead deficiency	Shaving of excess bone + subperiosteal bone graft and bioactive glass particles (NovaBone)
4	33 Y	F	Post surgical	Paranasal maxillary concavity	Subperiosteal bioactive glass particles
5	5 Y	F	Congenital	Cleft alveolus + anterior palatal fistula + parapyriform aperture maxillary deficiency	Closure of fistula + alveoloplasty using NovaBone + maxillary subperiosteal NovaBone
6	7 Y	F	Congenital	Cleft alveolus + anterior palatal fistula + parapyriform aperture maxillary deficiency	Closure of fistula + alveoloplasty using NovaBone + maxillary subperiosteal NovaBone
7	6 Y	M	Congenital	Cleft alveolus + anterior palatal fistula + parapyriform aperture maxillary deficiency	Closure of fistula + alveoloplasty using NovaBone + maxillary subperiosteal NovaBone

NovaBone is bioactive glass particles.

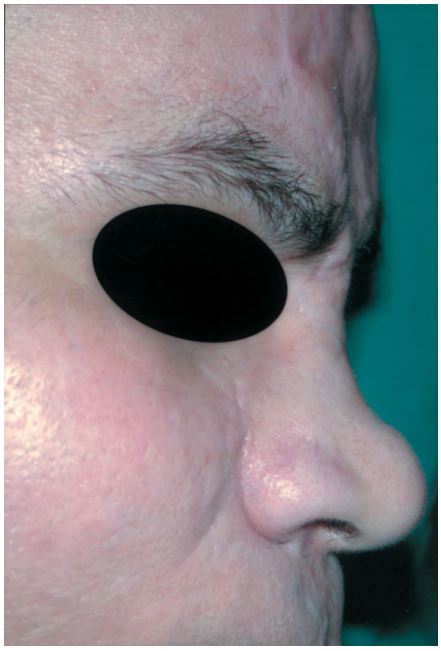

Fig. (1-A): A pre-operative photo for the patient numbered 1 in Table (1). It shows post traumatic mid-forehead depression and the saddle nose.

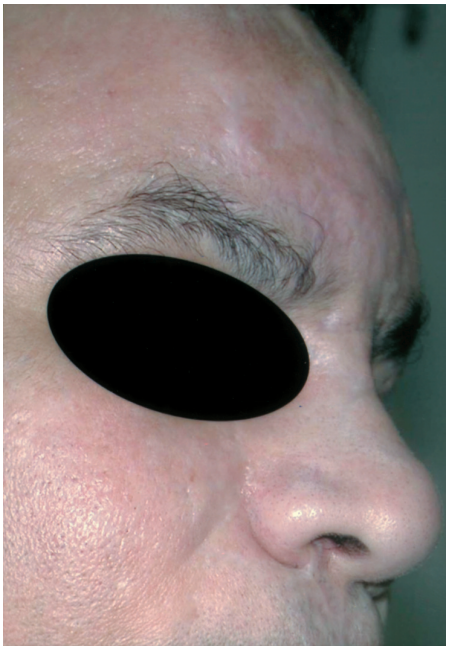

Fig. (1-B): A late post-operative photo for the patient numbered 1 in Table (1). It shows correction of both the mid-forehead depression by using the bioactive glass particles (NovaBone) and the saddle nose by using costal cartilage graft.

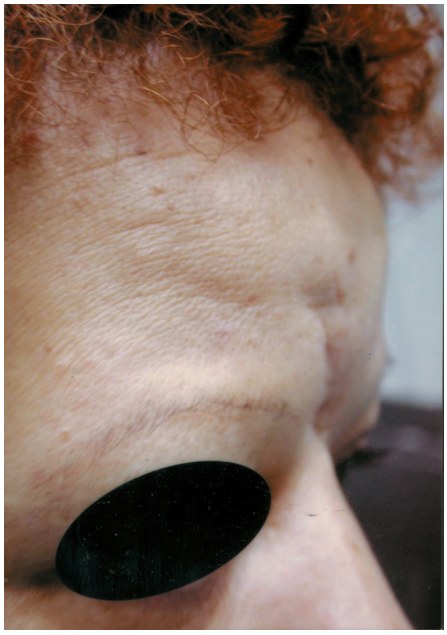

Fig. (2-A): A pre-operative photo for the patient numbered 2 in Table (1). It shows post traumatic mid-forehead depression.

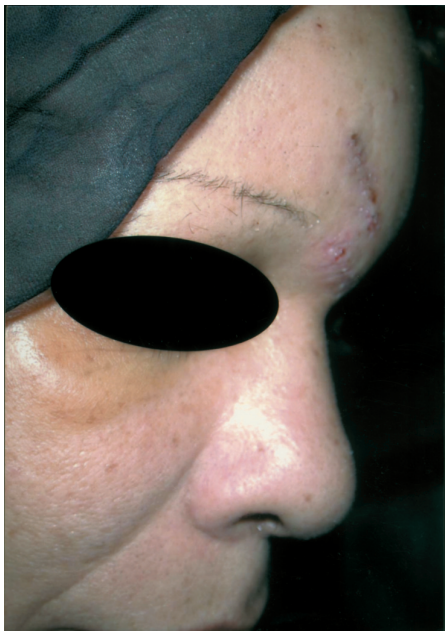

Fig. (2-B): An early post-operative photo for the patient numbered 2 in Table (1). It shows correction of the mid-forehead depression by using the bioactive glass particles (NovaBone).

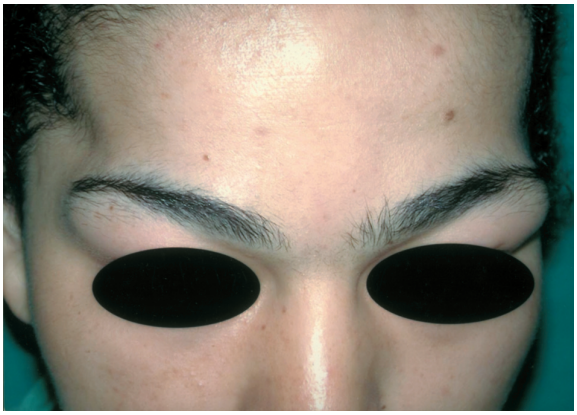

Fig. (3-A): A pre-operative photo for the patient numbered 3 in Table (1). It shows congenital supra-orbital hypertrophy and lateral forehead deficiency.

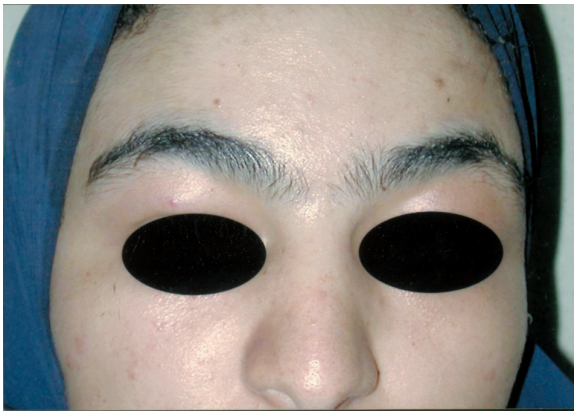

Fig. (3-B): A late post-operative photo for the patient numbered 3 in Table (1). It shows correction of the deformity by shaving of excess supra-orbital bone and subperiosteal bone graft and bioactive glass particles (NovaBone).

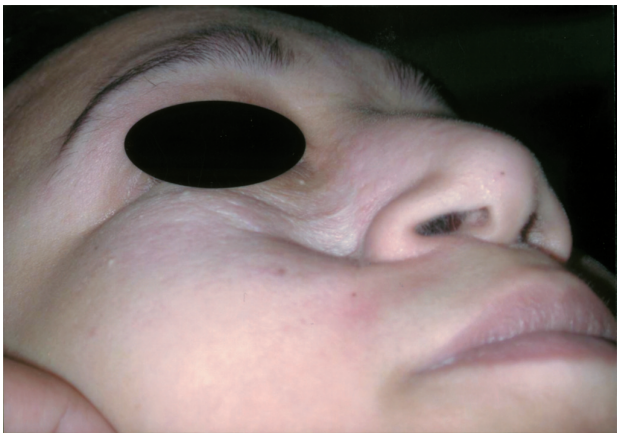

Fig. (4-A): A pre-operative photo for the patient numbered 4 in Table (1). It shows para-nasal maxillary concavity after complete cure of previous cutaneous mucor-mycosis.

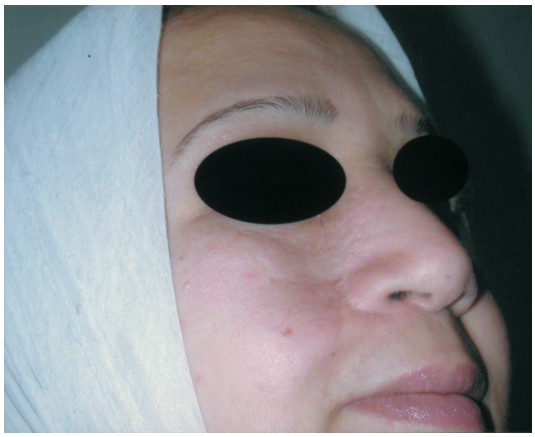

Fig. (4-B): A late post-operative photo for the patient numbered 4 in Table (1). It shows correction of the maxillary concavity by using subperiosteal bioactive glass particles (NovaBone).

DISCUSSION

Bioactive materials (like the bioactive glass particles) are defined as those that elicit a specific biological response at the interface of the material that results in the formation of a bond between the tissue and the material **[19]**. This osteointegration; the direct structural and functional union between live bone and the implant surface minimizes the formation of a fibrous capsule around the implant **[20]**. Therefore, unlike non-bioactive alloplasts, failure under mechanical stress does not occur at the bone interface, but rather occurs in the host bone or within the biomaterial. This absence of failure at the bone interface is a unique and defining feature of bioactive materials **[21]**.

Dual processes of bone formation distinguish bioactive glass from other synthetic biomaterials. Although osteoconductive bone growth occurs at the periphery of the granules, bone growth is also observed at the excavated cores of the granules located at some distance from existing bone tissue **[15,22,23]**. Virolainen et al., demonstrated that bioactive glass surface is not only osteoconductive but also osteoproductive **[24]**. Osteoproduction is defined as the process whereby a bioactive surface is colonized by osteogenic stem cells that are freed in the defect environment by surgical intervention **[25]**.

When bioactive glass is placed in contact with living tissue a series of surface reaction occurs.

Bioactive glass particles are excavated and transformed to a calcium and phosphate containing shell from which the interior silicon rich core is removed. It is in these excavated cores that new bone tissue starts to form without contact with the preexisting bone of the defect margin **[24]**. Release of silicon will stimulate the production of Transforming Growth Factor Beta (TGFβ) which serves as an osteogenic cytokine leading to a rapid proliferation of bone in contact with the glass particles **[26]**.

In this current work, the bioactive glass particles (NovaBone) were applied in a subperiosteal pocket in all cases. This has many advantages. First, it prevents migration of the bioactive glass particles from its site of application. This effect is additive to the negatively charged gel at the surface of the particles that hold the glass particles in a cohesive mass. Second, it allows adequate coverage and prevents exposure. Third, it allows only bony integration and prevents fibrous integration **[8,27]**. Fourth, the periosteum-being osteogenic-provides osteogenic cells which colonize and allows osteoproduction. Fifth, the periosteum-being vascularized-allows early mineralization **[27]**. Sixth, subperiosteal dissection is easier than supraperiosteal dissection and can be done blindly through small incision.

The incision in the periosteum in cases of posttraumatic forehead contouring was at a higher level than the incision at the skin to prevent bioactive glass particles loss if the two incisions were at the same level. The cut in the periosteum was at a level higher than the area to be contoured to guarantee that the whole NovaBone particles are covered by periosteum. This was not a problem in the case of congenital forehead deformity (congenital supraorbital hypertrophy and lateral forehead deficiency; frontometaphyseal dysplasia) because the periosteum was elevated away from the site of application. In cases of contouring deficient maxilla whether post surgical in the paranasal area (after eradication of fungal infection) or in cases of complete unilateral prealveolar and alveolar cleft, both periosteal and mucosal incisions were at the same level. This explains why loss of some of the bioactive glass particles (NovaBone) occurred in two cases of maxillary contouring.

Bioactive glass particles (NovaBone) contour easily to the skeletal deficiency. They do not need prefabrication as in bioactive glass ceramic implants **[1,13]**. The bioactive glass particles (NovaBone) offer the attractive possibility of contouring and molding minor defects after surgery by compression over the surgical site. This correction can be made even 2 to 3 days after surgery until the material is anchored to the underlying bone. No exposure of the bioactive glass particles (NovaBone) was noticed in any of the patients. This adds advantage for the bioactive glass particles (NovaBone) over the bioactive glass ceramic implants which were extruded in 20% of cases in the study of Duskova et al. **[1]** Duskova re-operated on these cases with implant size reduction or revision of the soft-tissue cover **[1]**. If the bioactive glass ceramic was not exactly prefabricated, there may be a visible or palpable step-off. This is not only specific to bioactive glass ceramic implant, but also to any block implant or bone graft **[28]**.

Most clinical reports of bioactive glasses deal with the repair of periodontal defects and alveolar ridge defects **[29-33]**. There was more limited experience with reconstruction of other areas of the head and neck. The use of bioactive glass implant for orbit and facial skeleton was documented by few authors **[1,34-37]**. The use of Bioactive glass particles for maxillary sinus augmentation and frontal sinus obliteration was reported by others **[22,38-42]**. Reconstruction of full thickness cranial defect was performed experimentally using NovaBone by Gosain, Elshahat et al. and Moreira-Gonzalez et al. **[15,43,44]**.

From previous review of clinical application of bioactive glass, this current study is the first to report the use of bioactive glass particles (NovaBone) in contouring craniofacial skeleton. The future carries the application of the bioactive glass particles (NovaBone) in aesthetic augmentation. This will be very attractive since the alteration of the bony foundation provides more consistent results than does the attempt of soft tissue contouring in the craniofacial region.

REFERENCES

1- Duskova M., Smahel Z., Vohradnik M., et al.: Bioactive glass-ceramics in facial skeleton contouring. Aesthetic Plast. Surg., 26: 274, 2002.

2- Byrd H.S., Hobar P.C. and Shewmake K.: Augmentation of the craniofacial skeleton with porous hydroxyapatite granules. Plast. Reconstr. Surg., 91 (1): 15; discussion 23, 1993.

3- Honig J.F. and Merten H.A.: Subperiosteal versus epiperiosteal forehead augmentation with hydroxyapatite for aesthatic facial contouring: Experimental animal investigation and clinical application. Aesthetic Plast. Surg., 17 (2): 93, 1993.

4- Satoh K. and Nakatsuka K.: Simplified procdure for aesthetic improvement of facial contour by maxillary augmentation using a porous hydroxyapatite graft for maxillofacial deformity. Plast. Reconstr. Surg., 97 (2): 338, 1996.

5- Frodel J.L. and Lee S.: The use of high-density polyethylene implants in facial deformities. Arch. Orolaryngol. Head Neck Surg., 124: 1219, 1998.

6- Yarmachuk M.J. and Israeli D.: Paranasal implants for correction of midface concavity. Plast. Reconstr. Surg., 102 (5): 1676; discussion 1685, 1998.

7- Baker S., Weinzweig J., Kirschner R. and Barlett S.: Applications of a new carbonated calcium phosphate bone cement: Early experience in pediatric and adult craniofacial reconstruction. Plast. Reconstr. Surg., 109: 1789, 2002.

8- Moreira-Gonzalez A., Jackson I.T., Miyawaki T., et al.: Augmentation of the craniomaxillofacial region using porous hydroxyapatite granules. Plast. Reconstr. Surg., 111 (6): 1808, 2003.

9- Tuncer S., Yavuzer R., Isik I., et al.: The fate of hydroxyapatite cement used for cranial contouring: Histological evaluation of a case. J. Craniofac. Surg., 15 (2): 243, 2004.

10- Magee W.P., Ajkay N., Freda N. and Rosenblum R.S.: Use of fast-setting hydroxyapatite cement for secondary craniofacial contouring. Plast. Reconstr. Surg., 114: 289, 2004.

11- Chen T.M., Wang H.J., Chen S.L. and Lin F.H.: Reconstruction of post-traumatic frontal-bone depression using hydroxyapatite cement. Ann. Plast. Surg., 52: 303, 2004.

12- Honig J.F., Merten H.A., Nitsch A. and Verheggen R.: Contouring of cranial vault irregularities with hydroxyapatite cement: A clinical and experimental investigation. J. Craniofac. Surg., 16 (3): 457, 2005.

13- Gosain A.K.: Bioactive glass for bone replacement in craniomaxillofacial reconstruction. Plastic Surgery Education Foundation Device and Technique Assessment Committee. Plast. Reconstr. Surg., 114 (2): 590, 2004.

14- Cho Y.R. and Gosain A.K.: Biomaterials in craniofacial reconstruction. Clin. Plast. Surg., 31 (3): 377, 2004.

15- Elshahat A., Shermak M.A., Inoue N., et al.: The use of NovaBone and Norian in cranioplasty: A comparative study. J. Craniofac. Surg., 15 (3): 483, 2004.

16- Blaydon S., Amato M.M., Neuhaus R. and Shore J.W.: The orbito-facial uses of NovaBone C/M, a bioactive glass synthetic bone graft particulate for craniofacoal and maxillofacial surgry. Presented at the American Society of Oculoplastic Plastic Reconstructive Surgery Scientific Symposium, Dallas, Texas, October, 20, 2000.

17- Salyer K.E.: Forehead and orbital surgery. In: Salyer K.E. (ed): Techniques in aesthetic craniofacial surgery. New York, Gower Medical Publishing (a division of J.B. Lippincott Company), Page 53, 1989.

18- Losee J.E., Selber J., Vega S., et al.: Primary cutaneous mucormycosis: Guide to surgical management. Ann. Plast. Surg., 49 (4): 385, 2002.

19- Hench L.L.: Bioceramics: Materials characteristics versus in-vivo behavior. In: Ducheyne P., Lemons J. (eds.). Ann. N. Y. Acad. Sci., 523: 54, 1998.

20- LeGeros R.Z. and Craig R.G.: Strategies to affect bone remodelling: osteointegration. J. Bone Miner. Res., 8: 583, 1993.

21- Hench L.I. and West J.K.: Biological applications of bioactive glasses. Life Chem. Rep., 13: 187, 1996.

22- Furusawa T. and Mizunuma K.: Osteoconductive properties and efficacy of resorbable bioactive glass as a cone grafting material. Implant. Dent., 6: 93, 1997.

23- Oonishi H., Kushitani S., Yasukawa E., et al.: Particulate bioglass compared with hydroxyapatite as a bone graft substitute. Clin. Orthop., 334: 316, 1997.

24- Virolainen P., Heikkila J., Yli-Urpo A., et al.: Histomorphometeric and molecular biologic comparison of bioactive glass granules and autogenous bone grafts in augmentation of bone defect healing. J. Biomed. Mater. Res., 35: 9, 1997.

25- Wilson J. and Low S.B.J.: Bioactive ceramics for periodontal treatment: comparative studies in the Patus monkey. Appl. Biomaterials, 3: 123, 1992.

26- Price N., Bendall S.P., Frondoza C., et al.: Human osteoblast-like cells (MG63) proliferate on a bioactive glass surface. J. Biomed. Mater. Res., 37: 384, 1997.

27- Elshahat A., Inou N., Marti G., et al.: Guided bone regeneration at the donor site of iliac bone graft for future use as autogenous grafts. Plast. Reconstr. Surg., 116 (4): 1068; discussion 1076, 2005.

28- Bucky L.P., Bartlett S.P. and Whitaker L.A.: Avoiding pitfalls and managing complications of asthetic contouring of the craniofacial skeleton. Clin. Plast. Surg., 24 (3): 613, 1997.

29- Quinones C.R. and Lovelace T.B.: Utilization of a bioactive synthetic particulate for periodontal therapy and bone augmentation techniques. Pract. Periodontics Aesthet. Dent., 9: 1, 1997.

30- Lovelace T.B., Mllonig J.T., Meffert R.M., et al.: Clinical evaluation of bioactive glass in treatment of periodontal osseous defects in humans. J. Periodontol., 69: 1027, 1998.

31- Sy I.P.: Alveolar ridge preservation using a bioactive glass particulate graft in extraction site defects. Gen. Dent., 50: 66, 2002.

32- Throndson R.R. and Sexton S.B.: Grafting mandibular third molar extraction sites: A comparison of bioactive glass to a nongrafted site. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 94: 413, 2002.

33- Norton M.R. and Wilson J.: Dental implants placed in extraction site implanted with bioactive glass: Human histology and clinical outcome. Int. J. Oral Maxillofac. Implants, 17: 249, 2002.

34- Sucominen E. and Kinnunen J.: Bioactive glass granules and plates in the reconstruction of defects of the facial bones. Scand. J. Plast. Reconstr. Hand Surg., 30: 281, 1996.

35- Kinnunen I., Aitasalo K., Pollonen M. and Varpula M.: Reconstruction of orbital floor fractures using bioactive glass. J. Craniomaxillofac. Surg., 28: 229, 2000.

36- Aitasalo K., Kinnunen I., Palmgren J. and Varpula M.: Repair of orbital floor fractures with bioactive glass implants. J. Oral Maxillofac. Surg., 59: 1390, 2001.

37- Amato M.M., Blaydon S.M., Scibbick F.W., et al.: Use of biolgass for orbital volume augmentation in enophthalmos: A rabbit model (oryctolagus cuniculus). Ophthal. Plast. Reconstr. Surg., 19 (6): 455, 2003.

38- Tadjoedin E.S., de Lange G.L., Lyaruu D.M., et al.: High concentrations of bioactive glass material (BioGran) vs. autogenous bone for sinus floor elevation. Clin. Oral Implants Res., 13: 428, 2002.

39- Peltola M., Suonpaa J., Aitasalo K., et al.: Obliteration of the frontal sinus cavity with bioactive glass. Head Neck, 20: 315, 1998.

40- Peltola M., Suonpaa J., Aitasalo K., et al.: Experimental follow up model for clinical frontal sinus obliteration with bioactive glass (S53P4). Acta. Otolaryngol. Suppl., 543: 167, 2000.

41- Peltola m., Aitasalo K., Suonpaa J., et al.: In vivo model for frontal sinus and calverial bone defect obliteration with bioactive glass S53P4 and hydroxyapatite. J. Biomed. Mater. Res., 58: 261, 2001.

42- Cordioli G., Mazzocco C., Schepers E., et al.: Maxillary sinus floor augmentation using bioactive glass granules and autogenous bone with simultaneous implant placement. Clinical and histological findings. Clin. Oral Implants Res., 12: 270, 2001.

43- Gosain A.K.: Biomaterials in facial reconstruction. Oper. Tech. Plast. Reconstr. Surg., 9: 23, 2003.

44- Moreira-Gonzalez A., Lobocki C., Barakat K., et al.: Evaluation of 45S5 bioactive glass combined as a bone substitute in the reconstruction of critical size calverial defects in rabbits. J. Craniofac. Surg., 16 (1): 63, 2005.