Bioactive glass S53P4 in spine surgery - results from a prospective 11-year-follow-up

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ROME SPINE 2011
7.12.2011
Clinical Development of S53P4

- 1st Frontal Sinus Obliteration
- 1st Benign Bone Tumor filling
- 1st Tibial Plateau Fracture repair
- 1st Posterolateral Lumbar Fusion
- 1st Mastoid Obliteration
- 1st Osteomyelitis Patient
What is a bioactive glass?

• A bone substitute inducing a specific biological activity in the body resulting in a chemical bond between the material and the tissue.

• The bioactivity of a glass is composition dependent.

• BG S53P4 (53% SiO$_2$, 23% Na$_2$O, 20% CaO, 4% P$_2$O$_5$ – BonAlive EU approval 2006)
What is a bioactive glass?

- A bone substitute *inducing a specific biological activity* in the body resulting in a chemical bond between the material and the tissue.
- Osteoconductive
- Osteostimulative, stimulates the growth and maturation of osteoblasts
- Antibacterial
- The bioactivity of a glass is composition and form dependent
- BG S53P4 (53% SiO$_2$, 23% Na$_2$O, 20% CaO, 4% P$_2$O$_5$)
What happens after implantation of bioactive glass?
- a complex reaction

Reactions within 0-12 hours

- Silica gel layer formation
- Bioactive glass granule
- pH increases
- Osmotic pressure
- Inhibits bacterial growth

Reactions within 12-72 hours

- CaO, P$_2$O$_5$
- Precipitation of CaP to silica gel layer
- CaP crystallizes → hydroxyapatite
- Silica gel layer
- pH increases
- Na$^+$ → NaOH
- Inhibits bacterial growth
Bactericidal effect of bioactive glass

- 6 powdered bioactive glasses / blood agar
- 29 aerobic bacterial species
  - *Staph aureus*
  - *Staph aureus* (MRSA)
  - *Staph epidermidis*
  - *Pseudomonas*
- S53P4 most effective

Bioactive glass S53P4 as bone graft substitute in treatment of osteomyelitis

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ABSTRACT

Bioactive glass (BAG)-S53P4 is an osteoconductive bone substitute with proven antibacterial and bone bonding properties. In a multicentre study 11 patients with verified chronic osteomyelitis in the lower extremity and the spine were treated with BAG-S53P4 as a bone substitute. The cavity bone defect and the surrounding of a spinal implant were filled with BAG-S53P4. The most common pathogen causing the infection was Staphylococcus aureus. The mean follow-up was 24 months (range 10–38). BAG-S53P4 was well tolerated. Nine patients healed without complications. One patient who achieved good bone formation sustained a superficial wound infection due to vascular problems in the muscle flap, and one patient had an infection due to a deep haematoma. This study shows that BAG-S53P4 is a good and well-tolerated bone substitute, and can be used in treatment of osteomyelitis with good primary results.

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Multicentre study on patients with verified osteomyelitis in 2007–2009

Eleven patients (nine males, two females) with a radiologically diagnosed osteomyelitis participated.

Osteomyelitis was verified on MRI (nine patients), or on CT scans (two patients).

Osteomyelitis was localized in the lower extremity in ten cases and in the spine in one case.
• 75-year old female suffering from severe back pain
• Spondylodiscitis was verified on MRI and CT with epidural abscess and destruction of LIII and LIV vertebral bodies
Epidural abscess formation at level of L III

Preoperative sagittal T2 weighted MRI (left) and CT (right)
Bioactive glass S53P4 as bone graft substitute in treatment of osteomyelitis

• 28.4.2009 Posterior decompression LII/III-LIII/IV, spondylodesis LIIV, lumbotomy, canalisation of paravertebral abscess, resection of LIII, IV, anterior decompression and reconstruction

• Bioactive glass
  – granule size 0.8–1.0mm
  – volume 32cc

• Postoperative antibiotic treatment
  – Meropenem, Vancomycin, Rifampicin, Levofloxacin

• Mycobacterium tuberculosis cultured postoperatively from abscess formation in psoas muscle
Bioactive glass S53P4 as bone graft substitute in treatment of osteomyelitis

Postoperative X-ray images
Bioactive glass S53P4 as bone graft substitute in treatment of osteomyelitis

Unpublished 2-years postoperative CT images: Solid fusion visible and the patient has fully recovered
Bioactive Glass in Degenerative Spine Surgery
Instrumented Spondylodesis in Degenerative Spondylolisthesis With Bioactive Glass and Autologous Bone

A Prospective 11-year Follow-up

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Abstract: A prospective long-term follow-up study of bioactive glass (BAG)-S53P4 and autogenous bone (AB) used as bone graft substitutes for posterolateral spondylodesis in treatment of degenerative spondylolisthesis during 1996 to 1998 was conducted. The surgical procedure was a standardized instrumented posterolateral fusion that used USS/VAS. BAG was implanted on the left side of the fusion bed and AB on the right side. The operative outcome was evaluated on x-rays and computed tomography scans, and a clinical examination was also performed. Seventeen patients (12 women, 5 men) participated in the 11-year follow-up. The mean Oswestry Disability Index score at the follow-up was 21 (range 0 to 52), compared with 49 (range 32 to 64) at the preoperative time. A solid bony fusion was seen on computed tomography scans on the AB side in all patients and on the BAG side in 12 patients. The fusion rate of all fusion sites (n = 41) for BAG as a bone substitute was 88% at the L4/5 level and 88% at the L5/S1 level. The use of BAG as a bone graft extender can be considered as a good alternative in spinal surgery in the future.

Key Words: bioactive glass, bone substitute, spinal fusion, spondylolisthesis

(J Spinal Disord Tech 2011;24:455-461)

thickening of the ligamentum flavum lead to spinal stenosis and cause neurogenic claudication. Treatment should begin with conservative measures such as physical therapy, the use of a brace, aerobic exercise, and proper pain treatment. Surgical treatment involves decompression and spondylodesis. Instrumented posterior spondylodesis with transpedicular screw fixation and autogenous bone (AB) grafting is a standard operative procedure in the treatment of degenerative spondylolisthesis, which produces better fusion rates than uninstrumented fusions.1,2 However, AB harvested from the iliac crest is associated with an increased operation time and blood loss, in addition to significantly increased postoperative morbidity. Moreover, the risk of chronic donor site pain should not be overlooked.3 Therefore, there is a need for a bone substitute that would prevent the risks related to the harvesting procedure and ideally still provide an environment for a solid fusion.

Bioactive glass (BAG), which was first discovered by Hench in the early 1970s,4 is an osteostimulative synthetic silica-based bioactive material with unique bone-bonding properties. It forms a chemical bond with hydroxyapatite, the natural inorganic salt in bone, and provides a scaffold for new bone formation.5 BAG
A prospective 11-year follow-up-degenerative spine

- A prospective long-term follow-up study of bioactive glass (BAG)-S53P4 and autogenous bone (AB) used as bone graft substitutes for posterolateral spondylodesis in treatment of twenty patients with degenerative spondylolisthesis during 1996-1997
- Standard transpedicular fusion with USS®/VAS instrumentation
- S53P4 BAG (1 to 2 mm) 25g (20-40g) and AB was placed on each posterolateral fusion bed
- 17 patients (12 female, 5 men) participated in the 11-year follow-up
A prospective 11-year follow-up-degenerative spine

Visual Analogue Scale for Pain
A prospective 11-year follow-up-degenerative spine

Oswestry Disability Index
A prospective 11-year follow-up-degenerative spine

• A solid bony fusion was seen on CT scans on the AB side in all patients and on the BAG side in 12 patients
• The fusion rate of all fusion sites (n=41) for BAG as a bone substitute was
  – 88% at the L4/5 level
  – 88% at the L5/S1 level
• The overall subjective satisfaction was better for 15 patients at the 11-year follow-up than before the operation
The patient is a 76-year old female treated for a L4/5 degenerative spondylolisthesis with instability symptoms and radicular pain in the lower extremities.

A. Preoperative T1 weighted sagittal MRI shows disc degeneration at L4/5 and segmental stenosis.

B. Functional X-ray images show loss of disc height and traction spurs at L4/5 and a 8mm L4 retrolithesis in forward bending.

C. AP plain X-ray shows straight posture and no signs of scoliosis preoperatively.

D. 1 year postoperative axial CT image at level of L4 shows a solid fusion on both the (*)autograft and on the (**)BG side.

E. Plain lateral X-ray images show fusion masses posteriorly.

F. Plain AP X-ray images show strong fusion on the autograft side and bridging osteophytes from L3.

G. 11.5 year postoperative axial CT image at level of L4 shows a solid fusion on both the (*)autograft and on the (**)BG side. H-I. Plain X-ray images show severe loss of disc height at adjacent level L3/4 with prominent anterior osteophytes and slight degenerative retrolisthesis of L3. Shown in AP view, L3 is fused to L4 on the right side and a slight degenerative scoliosis is observed above the fusion.
Bioactive Glass in Trauma Spine Surgery
Posterolateral spondylodesis with bioactive glass and autologous bone grafting in instrumented unstable lumbar spine burst fractures: A prospective 10-year follow-up study.

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Accepted for publication in Scandinavian Journal of Surgery 7.9.2011
Bioactive glass (BAG)-S53P4 was used as bone graft substitutes for posterolateral spondylodesis in treatment of unstable lumbar spine burst fractures during 1996-1998 was conducted.

Sixteen patients aged 31-58 (mean 49, SD 10) years with an unstable lumbar burst fracture (one patient had sustained two fractures) participated in this prospective study. Two patients had incomplete spinal cord injuries classified as Frankel C; the others were neurologically intact.
Prospective 10-year follow-up study-trauma spine

• Fractures were reduced and fixed using USS® instrumentation
• 23g (10-35g) BAG-S53P4 and AB was placed on each posterolateral fusion bed
• Ten patients (nine men, one woman) participated in the 10-year follow-up
• No additional operations or hardware removals had been performed after the primary operation
Prospective 10-year follow-up study-trauma spine

- A solid bony fusion was seen on CT scans on the AB side in all patients and on the BAG side in five patients, and a partial fusion in five patients, resulting in a total fusion-rate of 71% in the BAG group
- ODI 12 (range 0-46)
- VAS 1 (range 0-4)
- All patients had returned to their jobs. At the time of the 10-year follow-up, five of the ten patients were retired on the basis of their age, none because of their medical condition
Prospective 10-year follow-up study-trauma spine

A) Antero-posterior X-ray
B) Lateral view-on X-ray

Instrumented spinal fusion of a L3-burst fracture 10 years postoperatively. Bioactive glass was implanted posterolaterally on the left side (asterix) and autogenous bone on the right side. Fusion was observed on both sides on levels of L1-2, L2-3 and L3-4.
Conclusion

• Preliminary results suggest that bioactive glass S53P4 can be considered as a good, effective and usable material for the treatment of the infected spine but long term follow-up is still required.

• Bioactive glass S53P4 as a bone graft extender can be considered as a good alternative in degenerative and trauma spine surgery.