



VIII CONGRESSO
NAZIONALE
PIEDE DIABETICO
INTERASSOCIATIVO SID-AMD

Focus sul piede nella
gestione del diabete

ROMA, 18-20 GIUGNO 2026
HOTEL NH VILLA CARPEGNA

IV Sessione: avanzare nella cura del Piede Diabetico

Sostituti ossei ed osteomielite: tra controllo dell'infezione e rigenerazione ossea

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Clinica San Carlo – Paderno Dugnano**

L'osteomielite (OM) rappresenta una particolare **sfida** nel trattamento del piede diabetico



È associata ad un alto **rischio di amputazione e sepsi** e richiede per il suo trattamento l'approccio di un **team multidisciplinare**

Lipsky, B.A.; Berendt, A.R. Infectious Diseases Society of America Clinical Practice Guideline for the Diagnosis and Treatment of Diabetic Foot Infections. *Clin. Infect. Dis.* **2012**, 54, e132–e173.

Gli individui con DM sono a **maggior rischio** di sviluppare **osteomielite del piede** a causa di una combinazione di fattori:

- **neuropatia periferica**
- **arteriopatia periferica**
- **funzione immunitaria compromessa**

Lavery, L.A.; Armstrong, D.G. Diabetic foot syndrome: Evaluating the prevalence and incidence of foot pathology in Mexican Americans and non-Hispanic whites from a diabetes disease management cohort. *Diabetes Care* **2003**, 26, 1435–1438



Recommendation 7: In a person with diabetes, consider using a combination of probe-to-bone test, plain X-rays, and erythrocyte sedimentation rate, or C-reactive protein, or procalcitonin as the initial studies to diagnose osteomyelitis of the foot. (Conditional; Low)

Rationale: The diagnosis of osteomyelitis in the foot of a person with diabetes may be difficult, partly because of a lack of a universally accepted definition or criterion standard, and partly related to low levels of inter-test agreement among commonly used diagnostic tests.⁸⁸ Osteomyelitis may be present underlying any foot wound, especially those that have been present for many weeks or that are wide, deep, located over a bony prominence, showing visible bone, or accompanied by an erythematous, swollen ("sausage") toe⁸⁹.

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The International Working Group on the Diabetic Foot



IWGDF Infection Guideline



DIFFERENTI LOCALIZZAZIONI DELL'OSTEOMIELE



75%
avampiede



15%
calcagno



10%
altre



L'osteomielite del retropiede

comporta un rischio particolarmente elevato

di **amputazione maggiore**

Winkler, E.; Schöni, M.; Krähenbühl, N.; Uçkay, I.; Waibel, F.W.A. Foot Osteomyelitis Location and Rates of Primary or Secondary Major Amputations in Patients with Diabetes. *Foot Ankle Int.* **2022**, *43*, 957–967

TRATTAMENTO DELL'OSTEOMIELEITE

L'obiettivo primario nel trattamento dell'osteomielite rimane l'**eradicazione dell'infezione**.

La combinazione di *chirurgia conservativa* e *terapia antibiotica mirata* è il **gold standard** per la risoluzione dell'infezione ossea

Lázaro Martínez, J.L.; García Álvarez, Y. Optimal management of diabetic foot osteomyelitis: Challenges and solutions. *Diabetes Metab. Syndr. Obes.* **2019**, *12*, 947–959



**Dominant dorsalis
pedis artery**

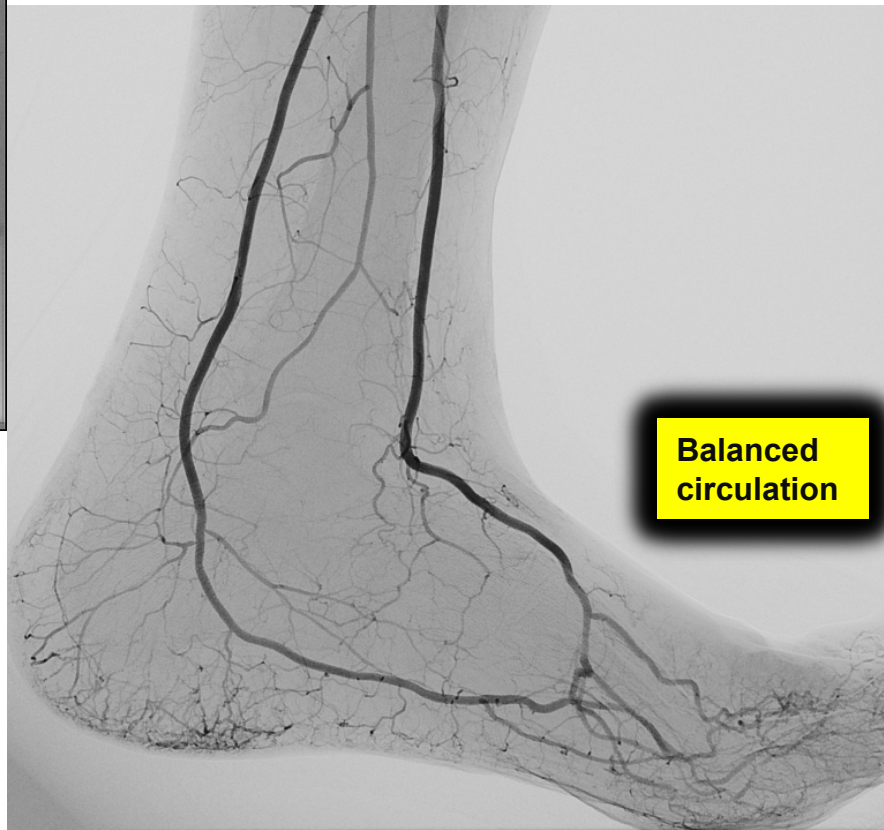


**Dominant lateral
plantar artery**



**NON DIMENTICARE
LA
VALUTAZIONE VASCOLARE !!**

**Balanced
circulation**



DIBATTITO del TRATTAMENTO DELL'OSTEOMIELITE

Sebbene la **resezione chirurgica** dell'osso infetto

sia ampiamente considerata il ***gold standard***,

diversi studi hanno dimostrato l'efficacia della **monoterapia antibiotica**

Game, F.L.; Jeffcoate, W.J. Primarily non-surgical management of osteomyelitis of the foot in diabetes.

Diabetologia **2008**, 51, 962–967

Da Ros, R.; Assaloni, R.; Michelli, A.; Brunato, B.; Miranda, C. Antibiotic and Surgical Treatment of Diabetic Foot

Osteomyelitis: The Histopathological Evidence. *Antibiotics* **2024**, 13, 1142

La terapia antibiotica nel trattamento dell'osteomielite

Nel trattamento dell'osteomielite del piede diabetico, la **terapia antibiotica è l'approccio cardine**. Richiede una somministrazione mirata basata sull'isolamento del patogeno tramite **biopsia ossea**

Table 5: Duration of antibiotic therapy according to the clinical situation

Infection severity (skin and soft tissues)	Route	Duration
Class 2: mild	oral	1-2 weeks*
Class 3 / 4: moderate / severe	oral/initially iv	2-4 weeks
Bone/joint	Route	Duration
Resected	oral/initially iv	2-5 days
Debrided (soft tissue infection)	oral/initially iv	1-2 weeks
Positive culture or histology of bone margins after bone resection	oral/initially iv	3 weeks
No surgery or dead bone	oral/initially iv	6 weeks

*: 10 days following surgical debridement

iv: intravenous



Recommendation 10: In a person for whom there is suspicion of osteomyelitis of the foot (before or after treatment), consider obtaining bone (rather than soft tissue) samples for culture, either intraoperatively or percutaneously. (Conditional; Moderate)

Recommendation 12d: If evidence of infection has not resolved after 4 weeks of apparently appropriate therapy, re-evaluate the patient, and reconsider the need for further diagnostic studies or alternative treatments. (Strong; Low)

Recommendation 13: Select an antibiotic agent for treating a diabetes-related foot infection based on: the likely or proven causative pathogen(s) and their antibiotic susceptibilities; the clinical severity of the infection; published evidence of the efficacy of the agent for infections of the diabetes-related foot; risk of adverse events including collateral damage to the commensal flora; the likelihood of drug interactions; agent availability and, costs. Best Practice Statement

Recommendation 17: Use the outcome at a minimum follow-up duration of 6 months after the end of the antibiotic therapy to diagnose remission of diabetes-related osteomyelitis of the foot. Best Practice Statement

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IWGDF Infection Guideline



I SOSTITUTI OSSEI sono a tutti gli effetti dei biomateriali

Vengono definiti come materiali biocompatibili
(di origine naturale o sintetici)
progettati per interagire con i tessuti del corpo umano allo scopo di

**sostituire,
supportare o
rigenerare**

il tessuto osseo mancante o danneggiato.

La storia dei biomateriali (1)

Dalle origini alla prima metà del XX secolo (L'era dei materiali bioinerti)

Preistoria: i primi tentativi risalgono all'antichità, con l'uso di avorio, legno o metalli per sostituire denti e arti mancanti.

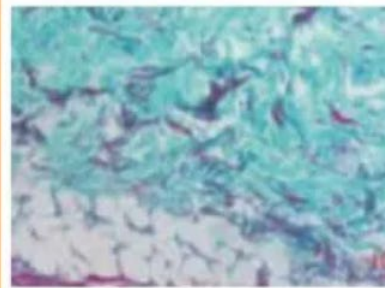
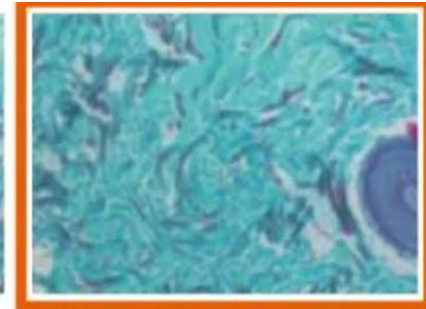
Biomateriali di **prima generazione**: il requisito fondamentale per il materiale è di essere bioinerte, ovvero biocompatibile



La storia dei biomateriali (2)

Gli anni '60 e '70 (L'era della bioattività)

Biomateriali di **seconda generazione**: si richiede al materiale di essere bioattivo, o riassorbibile, cioè degradarsi chimicamente e riassorbirsi in maniera controllata, in modo da essere sostituito dal tessuto che lo ospita.

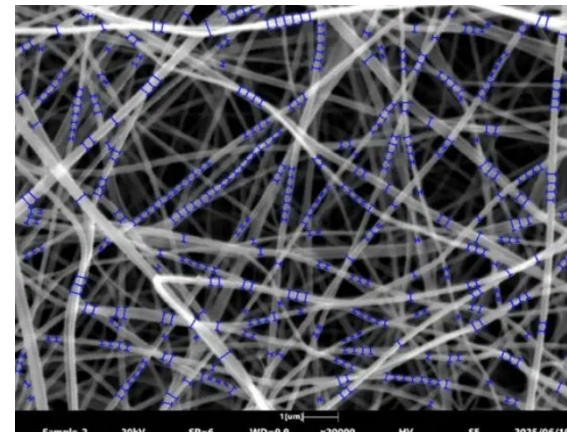
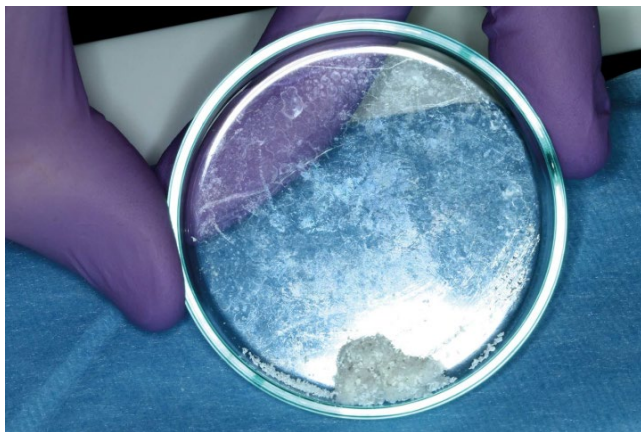


La storia dei biomateriali (3)

Dai primi anni 2000 a oggi (L'era dell'ingegneria tissutale)

I biomateriali di ultima generazione sono basati sull'ingegneria dei tessuti. Non solo si integrano con il corpo, ma inviano segnali cellulari per rigenerare i tessuti danneggiati, utilizzando materiali come l'acido ialuronico

Biomateriali di **terza generazione**: il materiale deve essere sia bioattivo che riassorbibile, [biodegradabile](#)



I biomateriali

si possono classificare in base alla *natura chimica* del materiale stesso:

metallici,
polimerici,
ceramici e
compositi

Possono anche essere di derivazione biologica

SOSTITUTI OSSEI

I sostituti ossei sono dispositivi medici utilizzati in ortopedia, odontoiatria e chirurgia maxillo-facciale per colmare difetti scheletrici.

I prodotti in commercio si dividono principalmente in tre categorie:

- **sintetici**
- **eterologhi** (di origine animale)
- **allogenici** (da donatore umano)

.... tutti progettati per stimolare l'osteoconduzione



SOSTITUTI OSSEI

1. Sostituti Ossei Sintetici

Realizzati in laboratorio, sono totalmente sterili e si riassorbono nel tempo lasciando spazio al nuovo osso.

Idrossiapatite e fosfato tricalcico: Ceramiche a base di fosfato di calcio, ideali come scaffold strutturali

2. Sostituti Ossei Eterologhi (Xenogenici)

Derivano da matrice minerale animale (solitamente bovina o equina) privata di qualsiasi cellula vitale per azzerare il rischio di rigetto

3. Sostituti Ossei Allogenici

Costituiti da tessuto osseo umano prelevato da donatori e trattato nelle "Banche dell'Osso" per sterilizzarlo e renderlo sicuro. Mantiene intatta l'impalcatura organica e inorganica originaria

Sostituti Ossei con Antibiotico

Sostituti ossei porosi o a base di solfato di calcio vengono saturati con antibiotici (**Vancomicina, Rifampicina, Gentamicina e Tobramicina**) prima dell'inserimento.

Questo permette un rilascio locale, controllato e ad alte concentrazioni direttamente nella sede infetta.

Si raggiungono, così, localmente concentrazioni superiori alla soglia minima inibitoria (MIC)

Vengono spesso utilizzati in una procedura chirurgica a due stadi (rimozione dell'infezione e, in un secondo momento, ricostruzione)

Sostituti Ossei senza Antibiotico

Permettono una elevata stabilità volumetrica a lungo termine e, nei casi di **vetro bioattivo**, garantiscono una proprietà antimicrobica intrinseca che contrasta i batteri senza aggiungere farmaci specifici.

Vengono spesso utilizzati in una procedura chirurgica **one-step** (rimozione dell'infezione e, nello stesso momento, ricostruzione)

SOSTITUTI OSSEI



90 aziende | 269 prodotti



BIOVETRI

Il professor **Larry Hench** li scoprì nel 1969 presso l'Università della Florida a Gainesville.
Il biovetro è una ceramica vetrosa composta da :

Biossido di silicio (45%)
Ossido di sodio (24.5%)
Ossido di calcio (24.5%)
Pentossido di fosforo (6%)



Tabella 2.3 Composizione di alcuni vetri bioattivi[9].

Composition (wt%)	45S5	13-93	6P53B	58S	70S30C	13- 93B1	13- 93B3	P₅₀C₂₅N₂₅
Na ₂ O	24.5	6.0	10.3	0	0	5.8	5.5	9.3
K ₂ O	0	12.0	2.8	0	0	11.7	11.1	0
MgO	0	5.0	10.2	0	0	4.9	4.6	0
CaO	24.5	20.0	18.0	32.6	28.6	19.5	18.5	19.7
SiO ₂	45.0	53	52.7	58.2	71.4	34.4	0	0
P ₂ O ₅	6.0	4.0	6.0	9.2	0	3.8	3.7	71.0
B ₂ O ₃	0	0	0	0	0	19.9	56.6	0

S53 P4

Vetro bioattivo :

53% SiO_2 di biossido di silicio
23% Na_2O di ossido di sodio
20% CaO di ossido di calcio e
4% P_2O_5 di pentossido di fosforo

Efficacia ad ampio spettro

I granuli **S53P4** granules risultano efficaci nell'inibire la proliferazione di oltre 50 specie batteriche comuni (fra cui *MRSA* e *MRSE*).

Batteri Gram-positivi

Bacillus cereus
Bifidobacterium adolescentis
Clostridium difficile
Clostridium perfringens
Clostridium septicum
Corynebacterium ulcerans
Enterobacter cloacae
Enterococcus faecalis
Enterococcus faecium
Eubacterium lenium
Listeria monocytogenes
Micrococcus sp.
Mycobacterium tuberculosis
Pepiostreptococcus anaerobius
Pepiostreptococcus magnus
Propionibacterium acnes
Propionibacterium propionicus
Staphylococcus aureus
Staphylococcus epidermidis
Staphylococcus hominis
Staphylococcus lugdunensis
Streptococcus agalactiae
Streptococcus mutans
Streptococcus pneumoniae
Streptococcus pyogenes
Streptococcus sanguis

Batteri Gram-negativi

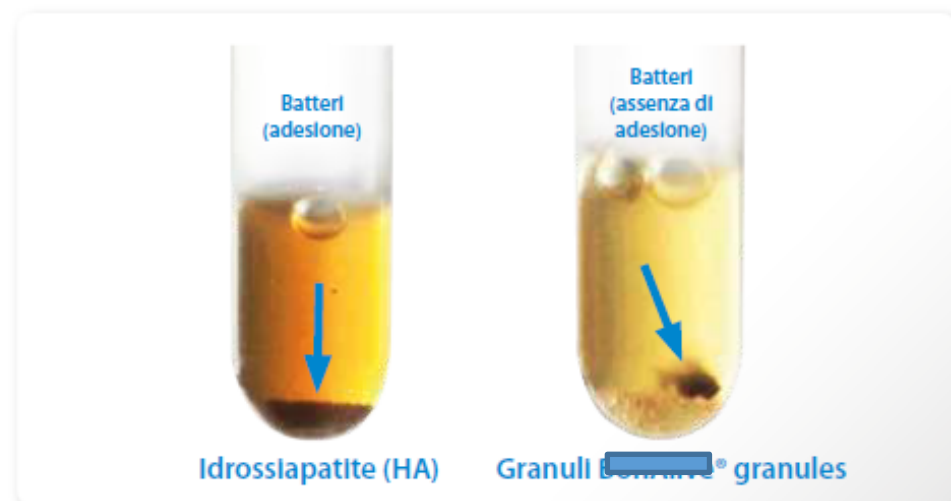
Acinetobacter baumannii
Bacteroides fragilis
Bacteroides thetaiotaomicron
Chryseobacterium (in precedenza Flavobacterium) meningosepticum
Enterobacter aerogenes
Enterobacter amnigenus
Escherichia coli
Fusobacterium necrophorum
Fusobacterium nucleatum
Haemophilus influenzae

Klebsiella pneumoniae

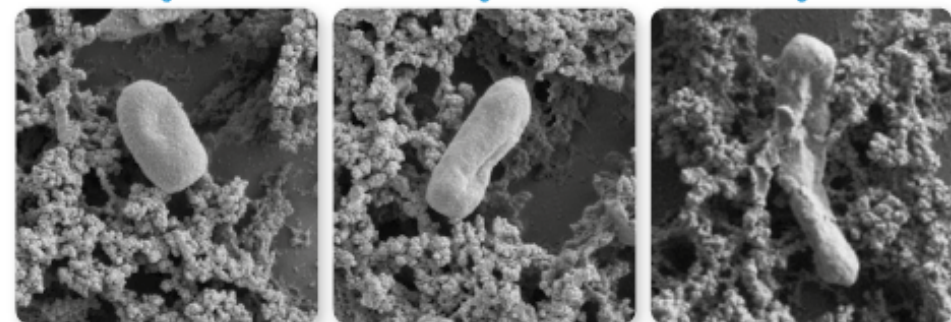
Monaxella castralis
Neisseria meningitidis
Pasteurella multocida
Porphyromonas gingivalis
Prevotella intermedia
Prevotella melaninogenica
Proteus mirabilis
Pseudomonas aeruginosa
Salmonella typhimurium
Shigella sonnei
Veillonella parvula
Yersinia enterocolitica

Batteri resistenti alla meticcillina

Pseudomonas aeruginosa
Staphylococcus aureus (MRSA)
Staphylococcus epidermidis (MRSE)



I test batteriologici eseguiti utilizzando ceppi di *Porphyromonas gingivalis* pigmentati mostrano che i batteri non riescono ad aderire e proliferare sulla superficie dei granuli **S53P4** granules.



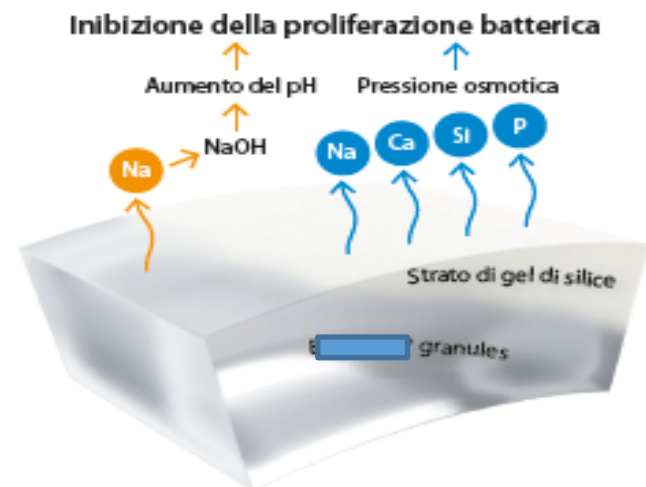
Le immagini illustrano l'effetto del cristallo bioattivo S53P4 sui batteri *Staphylococcus aureus*, *Klebsiella pneumoniae* e *Acinetobacter baumannii*, resistenti alla meticcillina. L'inibizione della proliferazione batterica è rilevabile tramite variazioni morfologiche dei batteri quali deformazione delle cellule e comparsa di fori nelle membrane cellulari.

Scor P. et al. 1996

Porphyromonas gingivalis da Prof. Lorenzo Drago, Università di Milano, Italia

Inibizione della proliferazione batterica

granules inibisce la proliferazione batterica, ma non contiene antibiotici.^{2,3} Il meccanismo opera mediante il rilascio di ioni che danno origine a un ambiente alcalino (pH elevato) e a un aumento della pressione osmotica all'interno del difetto osseo.¹



Effetto del vetro bioattivo S53P4 su *Klebsiella pneumoniae*, resistente alla meticillina. L'inibizione della proliferazione batterica è rilevabile tramite variazioni morfologiche dei batteri.



Mastoidectomy cavity obliteration with bioactive glass: a pilot study

Juha Tapio Silvola ¹

Affiliations + expand

PMID: 22371341 DOI: 10.1177/0194599812438168

Abstract

Objective: To show that mastoid cavities with continuous infections and cleaning problems can be obliterated with bioactive glass (BG) and to present results of a pilot study for 16 operations on adults.

Study design: Case series with planned data collection.

Setting: Päijät-Häme Central Hospital, Finland-a single ear, nose, and throat (ENT) hospital department serving a population of 216,000.

Subjects and methods: Fourteen patients had a large open radical cavity with recurrent infections. Two ears had discharge and pain after simple mastoidectomy. A re-mastoidectomy included support of the cavity skin and obliteration with BG. The mean follow-up time was 2.2 years.

Results: All ears became dry. One reoperation was needed as the fascia support to the ear canal (EC) skin was too weak, and part of the BG leaked into the EC. The ear stayed dry, and the missing BG was replaced in a reoperation. A slightly short musculoperiosteal flap supported the EC skin in 1 ear. A minor amount of BG leaked into the EC. The ear stayed dry. The aim was an ample ear canal. One ear was overfilled and required meatoplasty. Simple mastoid cavities were isolated from the middle ear and become asymptomatic.

Conclusions: In this pilot study, BG works safely and with success as an obliteration material in problematic open radical cavities. Bioactive glass seems to tolerate chronic infection in the mastoid and prevent postoperative infections.

Posterolateral spondylodesis using bioactive glass S53P4 and autogenous bone in instrumented unstable lumbar spine burst fractures. A prospective 10-year follow-up study

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Affiliations + expand

PMID: 22414472 DOI: 10.1177/145749691210100113

Abstract

Background and aims: 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 unstable lumbar spine burst fractures during 1996-1998 was conducted.

Material and methods: The lumbar fractures were fixed using posterior USS instrumentation. 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 CT scans, and a clinical examination was also performed.

Results: The Oswestry score was excellent, and the mean pain score 1. The mean compression rate of the injured vertebral body was 25%. 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% of all fused segments in the BAG group.

Conclusions: Our long-term results show that BAG-S54P4 bone graft material is safe to be used as a bone graft extender in spine surgery.



ELSEVIER

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Efficacy and Safety of Bioactive Glass S53P4 as a Treatment for Diabetic Foot Osteomyelitis

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ABSTRACT

Osteomyelitis represents a challenging condition in the diabetic foot with an associated high risk of major amputation. S53P4 Bioactive Glass (BG) has bacterial inhibiting properties on the market and indicated to be used in osteomyelitis. The objective of the study was to test the efficacy and safety of BG in treating diabetic foot osteomyelitis. This was an observational, retrospective, single-centre study involving subjects with diabetes affected by osteomyelitis of the foot who underwent surgical debridement from 01/2016 to 10/2018. Overall, 44 diabetic patients (14 [31.8%] female, aged 68.0 ± 10.2 years, diabetes duration 26.8 ± 11.9 years) were studied: 22 (50%) treated with surgical debridement and a local application of BG; 22 (50%) treated by means of surgical debridement. The primary outcome was the osteomyelitis resolution. Revascularization was performed before surgical procedure in 31 (70.5%) of patients. Systemic antibiotics were used in both groups. The osteomyelitis resolution rate was significantly higher in subjects treated with BG than in subjects treated with traditional procedure (18 [90%] vs 13 [61.9%], respectively $p = .03$). The odds of BG to reach osteomyelitis resolution was 5.54 times greater than for traditional treatment (odds ratio 5.54, 95% confidence interval 1.10–30.5). The use of BG was associated with an 81% lower proba-

Pilot Experience on the Use of S53P4 Bioactive Glass in the Surgical Management of Diabetic Foot Osteomyelitis

Elisabetta Iacopi ¹, Letizia Pieruzzi ¹, Chiara Goretti ¹, Alberto Piaggese ¹

Affiliations + expand

PMID: 32506987 DOI: [10.1177/1534734620926003](https://doi.org/10.1177/1534734620926003)

Abstract

To test safety and efficacy of bioactive glass, a novel material used to replace bone, able to completely bond itself to the host tissues on patients treated for osteomyelitis (OM) complicating a diabetic foot (DF). We evaluated a group of patients consecutively admitted in our department between September and December 2018, who underwent surgical DF procedures for OM and in whom the use of bioactive glass could limit the demolition phase of surgical procedure. Patients were treated with bioactive glass S53P4 on top of standard treatment directly in operating room. The patients were weekly controlled for 6 months or until complete healing. During follow-up, we analyzed primarily healing rate and secondarily time of healing, need for further debridement procedures, recurrences, and adverse or hypersensitivity reactions to study treatment. Ten DF patients were enrolled (male/female 6/4; mean age 56 ± 11 years; mean duration of diabetes 10.5 ± 4.7 years, mean hemoglobin A1c $7.2 \pm 0.9\%$). Patients underwent surgical procedure during which, after an accurate debridement, bioactive glass was applied. A healing rate of 80% in a mean time of 34 ± 2 days, with only 1 patient who needed a second surgical look, was observed. Neither recurrences nor adverse events during follow-up were observed in treated patients. This pilot experience demonstrated that bioactive glass can be considered a useful tool for the surgical treatment of DF-related OM.

doi: 10.1177/15347346221102643. Epub 2022 May 18.

Bioactive Glass in a Multi Drug Resistance Osteomyelitis in Diabetic Foot: Case Report

Andrea Panunzi ¹, Laura Giurato ¹, Marco Meloni ¹, Luigi Uccioli ¹

Affiliations + expand

PMID: 35585695 DOI: [10.1177/15347346221102643](https://doi.org/10.1177/15347346221102643) [↗](#)

Abstract

Diabetic foot osteomyelitis (DFO) is a clinical problem with high risk of amputation. The treatment of DFO is still an unsolved challenge. Surgical therapy, antibiotic therapy or conservative treatment are still debated for the timing and the consequences. Long antibiotic therapies expose the selection of multidrug-resistant bacteria. Nowadays the use of new bone substitutes aims to support the load of the bone segments and to ensure the eradication of the infectious process after surgical treatment. A case report of digital osteomyelitis due to a multidrug resistant bacteria was treated with a conservative treatment and use of bioglass (Bonalive) that has the ability to inhibit bacterial growth. A long follow-up shows the resolution of infectious process, no ulcer recurrence and persistent recovery of its ability to walk. Our results agree with literature data and suggest that bioglass may be

CLINICAL CASE

- Female, aged 68
- Type 2 diabetic since 2000
- Thyroidectomy for nodules, in substitutive therapy with LT4
- Smoker: 10 /dye
- Three months before start of lesion to the first metatarsal of the right foot
- Comes to our attention for the first time with ulcer I metatarsal ray and positive test probe to bone, previously treated with different therapies without healing.



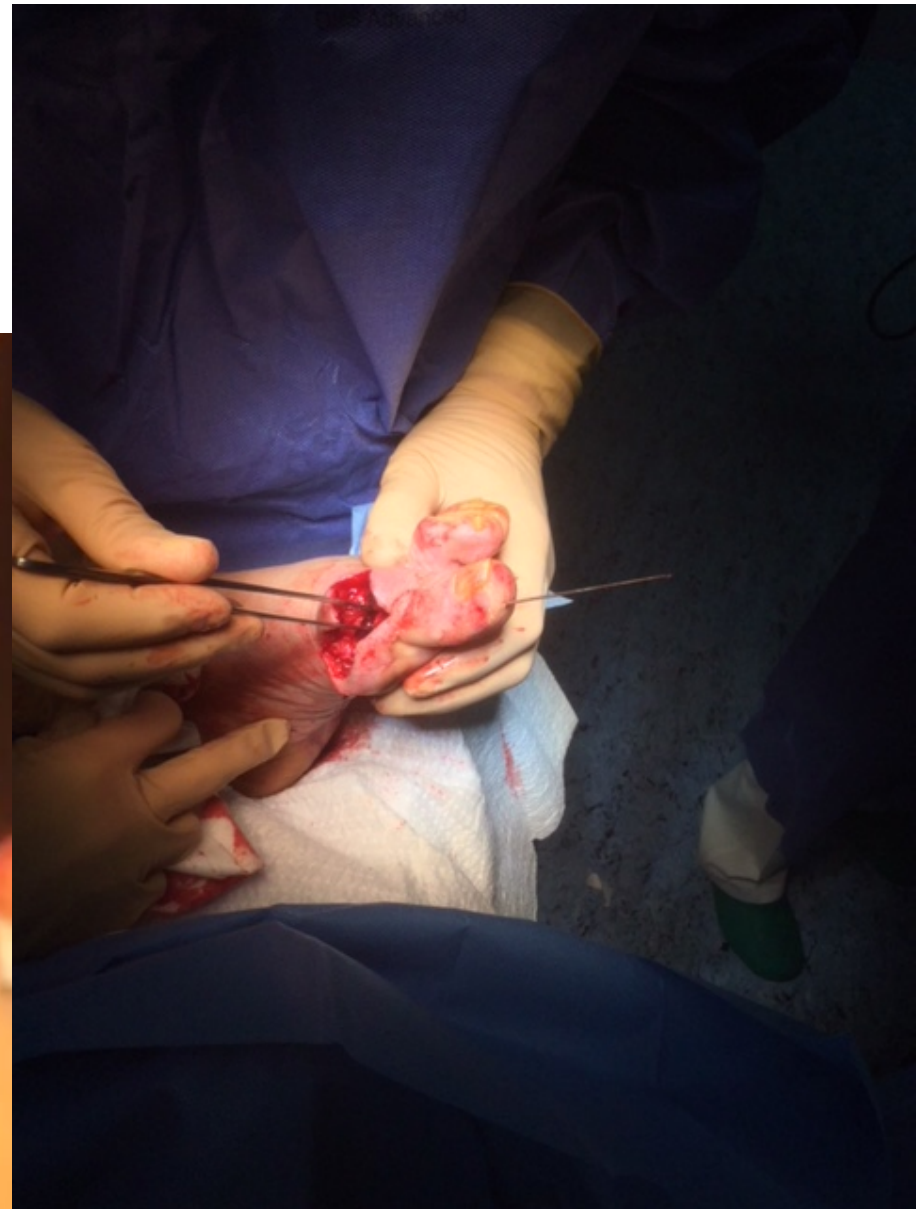
Surgical bone
debridement : on
December 21°,
2017

Antibiotic therapy with
Piperacillin/tazobacta
m
4,5 gr x 3/die

No vascular problem



Surgical debridement
of the osteomyelitis
and stabilization of the
metatarsal ray with
K-wires arthrodesis



7 weeks later

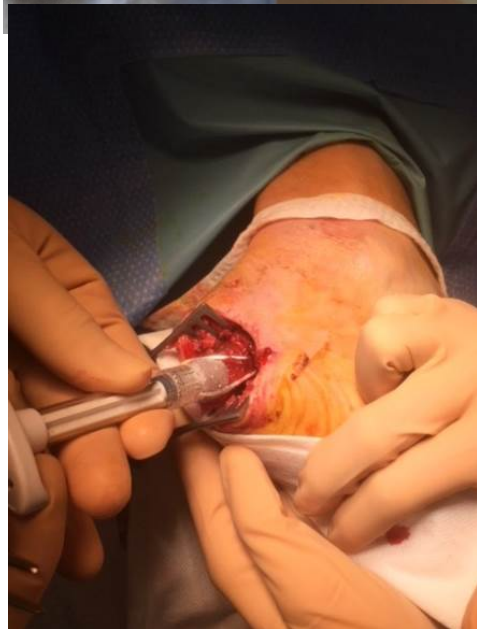
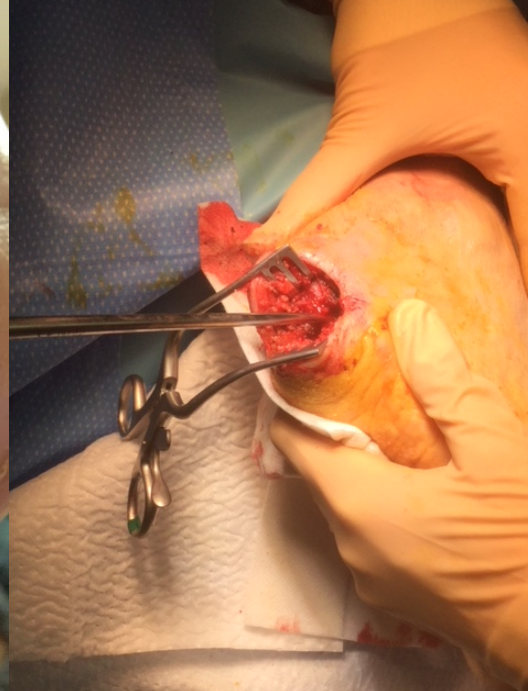


9 weeks later



20 weeks later







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In conclusione

Attualmente in letteratura **non esistono evidenze forti (di livello 1)**

come ampi studi clinici randomizzati e controllati (RCT)

che indichino un sostituto osseo sicuramente superiore

nel trattamento dell'osteomielite del piede diabetico



I vantaggi dell'utilizzo dei sostituti ossei (1)

Viene **trasformato** l'approccio chirurgico

da demolitivo a conservativo

rispettando maggiormente la

biomeccanica del piede



I vantaggi dell'utilizzo dei sostituti ossei (2)

Rilascio mirato del farmaco

(nel caso di quelli caricati con antibiotico)

o inibizione della carica batterica

(nel caso del biovetro attivo)

I vantaggi dell'utilizzo dei sostituti ossei (3)

**Riduzione dei tempi di
somministrazione della terapia
antibiotica sistemica**

I vantaggi dell'utilizzo dei sostituti ossei (4)

Rigenerazione tissutale

(essendo materiali biocompatibili,
biodegradabili e osteoconduttivi)

**favorendo la crescita di
nuovo tessuto osseo**



Diabetic foot care requires a true **MULTIDISCIPLINARY TEAM**



..... it's challenging.



G r a z i e !



L'osteomielite può interessare qualsiasi osso del piede ma soprattutto coinvolge con maggiore frequenza le ossa dell'avampiede (90%), seguito dal mesopiede (5%) e dal retropiede (5%). L'osteomielite dell'avampiede si associa ad una prognosi migliore rispetto a quella del meso e retropiede. Il rischio di amputazione al di sopra della caviglia è significativamente più alto per il retropiede (50%), rispetto al mesopiede (18.5%) e rispetto all'avampiede (0.33%) (16-18).

Aragon-Sanchez J, Lazaro-Martinez JL, Hernandez-Hettero C, Campillo-Vilorio N, Quintana_marrero Y, Garcia-Morales E and Hernandez-Herrero MJ. Does osteomyelitis in feet of patients with diabetes really recur after surgical treatment? Natural history of a surgical series. Diabet Med 29: 813-818, 2012

Aragon-Sanchez FJ, Cabrera-Galvan JJ, Quintana-Marrero Y, et al. Outcomes of surgical treatment of diabetic foot osteomyelitis: a series of 185 patients with histopathological confirmation of bone involvement. Diabetologia 51: 1962-1970, 2008.



Take-home messages 1

- **Don't ignore any lesion in a diabetic foot, consider it very insidious**
- **Perform close and careful monitoring of the evolution of a lesion**
- **Carefully evaluate the vascular situation**

Take-home messages 2

- **Share surgical aspects with other specialists and don't forget the importance of biomechanical issues**
- **In diabetic foot surgery, look for the solution of a minor amputation; it will be useful both for the patient's future and for his quality of life**
- **Don't forget the patient but follow him in prevention**