Biomechanical and histological evaluation of implants biofunctionalized by the bioactive glass: a preclinical study in hyperglycemic rabbits

Ísis de Fátima Balderrama[1,6]; Paola Faria da Silva[1]; Guilherme José Pimentel Lopes de Oliveira[2]; Renata Pires de Assis[3]; Edgar Dutra Zanotto[4]; Paulo G. Coelho[5]; Lukasz Witek[6]; Elcio Marcantonio Júnior[1]

(1) Department of Diagnosis and Surgery, Araraquara School of Dentistry, Sao Paulo State University, Araraquara, Sao Paulo, Brazi

(2) Department of Periodontology, School of Dentistry at Uberlandia, Federal University of Uberlandia, Uberlandia, Brazil

(3) Department of Clinical Analysis, School of Pharmaceutical Sciences, Sao Paulo State University, Araraquara, Sao Paulo, Brazil

(4) Vitreous Materials Laboratory, Department of Materials Engineering, Federal University of Sao Carlos, Sao Carlos, Brazil

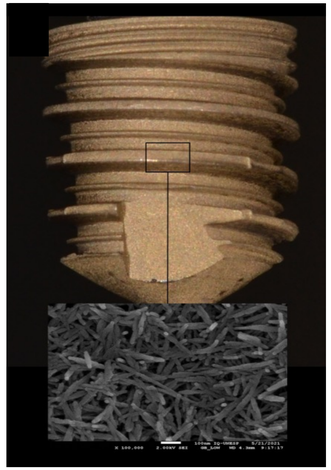
(5) DeWitt Daughtry Family Department of Surgery, Miller School of Medicine, University of Miami, Miami, United States

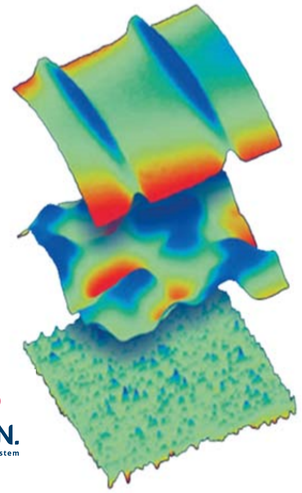
(6) Department of Molecular Pathobiology, Division of Biomaterials, New York University, New York, United States

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Introduction

OSSEOINTEGRATION:
- implant design
- **physicochemical properties of the surface**
- bone quality
- surgical techniques





S.I.N. Implant System

Bioactive glasses are highly active materials that can induce the upregulation of osteoblasts proliferation and differentiation resulting in a biologically active bone on their surface.

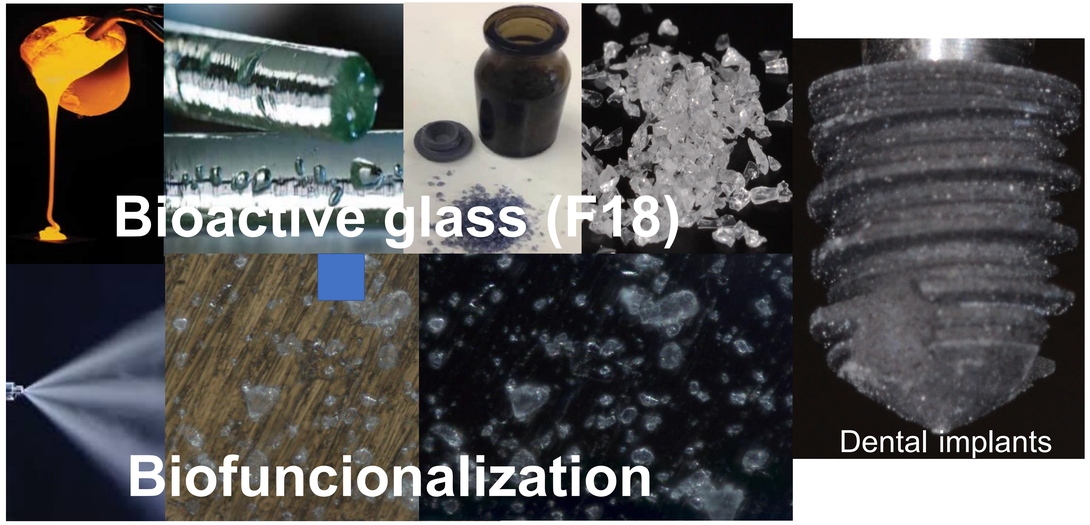
CeRTEV Center for Research, Technology and Education in Vitreous Materials

UFSCAr, Brazil
Zanotto Lab

A new bioglass (**BSF18**) protected by patent (2014; 003817-5, Brazil), was developed to improve the osseointegration response.

Biofuncionalization with bioactive glass F18 into surfaces

SiO_2-CaO-Na_2O-MgO-K_2O-P_2O_5. system



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ORIGINAL RESEARCH — WILEY CLINICAL ORAL IMPLANTS RESEARCH

Effect of titanium surface functionalization with bioactive glass on osseointegration: An experimental study in dogs

Priscilla Barbosa Ferreira Soares[1] | Camilla Christian Gomes Moura[1] | Clever Ricardo Chinaglia[2] | Edgar Dutra Zanotto[2] | Darceny Zanetta-Barbosa[1] | Andreas Stavropoulos[3]

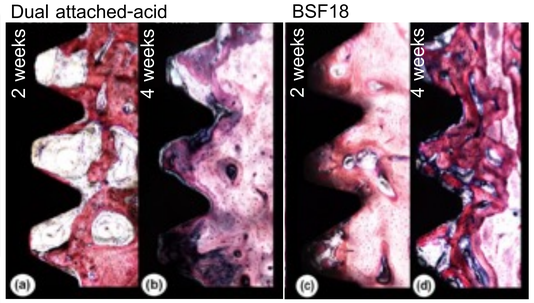
Naujokat *et al. International Journal of Implant Dentistry* (2016) 2:5
DOI 10.1186/s40729-016-0038-2

International Journal of Implant Dentistry
a SpringerOpen Journal

REVIEW — Open Access

Dental implants and diabetes mellitus—a systematic review

Hendrik Naujokat*, Burkhard Kunzendorf and Jörg Wiltfang



Open question (?)

diabetic patients

poor quality of bone

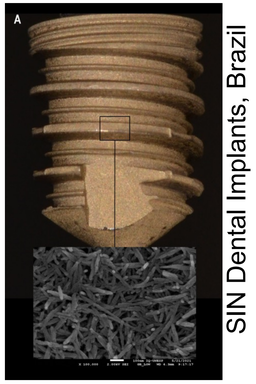
Aim

To evaluate in normoglycemic and hyperglycemic rabbits the biomechanical and histological analysis of implants with nanohydroxyapatite surface or biofunctionalized with bioactive glass

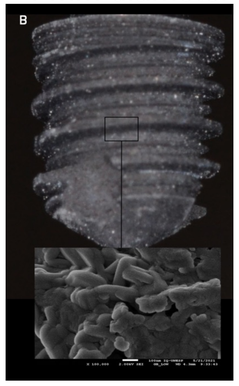
Methods

Surfaces

5 mm length
4 mm diameter

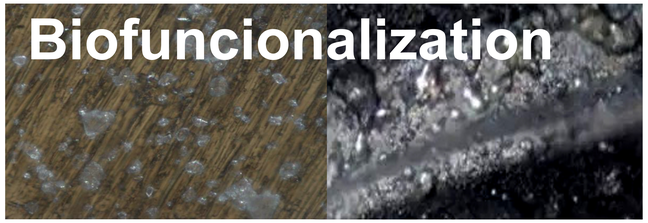


SIN Dental Implants, Brazil



Nano hydroxyapatite (Nano-Ha)

Biofuncionalization with bioactive glass (BSF18)



Physical-chemical properties of the surface:
Scanning electron microscopy
Energy dispersive x-ray
Wettability
Bioactivity
Roughness (AFM)

Center for Research Technology and Education in Vitreous Materials, CeRTEV, Brazil

Induction of Diabetes Mellitus

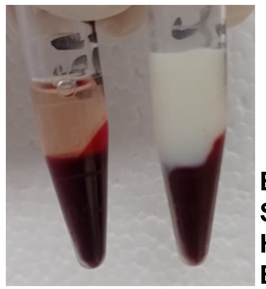
Day -3

Groups

G1: hyperglycemic rabbits with Nano-Ha
G2: hyperglycemic rabbits with BSF18
G3: normoglycemic rabbits with Nano-Ha
G4: normoglycemic rabbits with BSF18

G1 and G2 (hyperglycemic):
Intravenous injection of Alloxan (105 mg/kg)
- Fasting 12 hours
- 5% glucose solution
- Criteria: >300 mg/dL

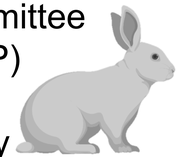
G3 and G4 (normoglycemic):
Saline Solution
- Criteria: 75 mg/dL to 155 mg/dL



Blood samples were collected:
Serum glucose
HbA1c
Biochemistry parameters

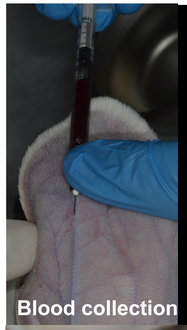
Surgery

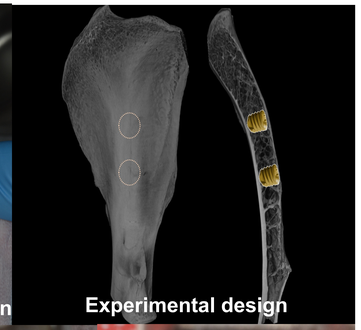
Animal Ethics Committee
(n. 11/2021, UNESP)
16 albino rabbit
Iliiac bone bilaterally

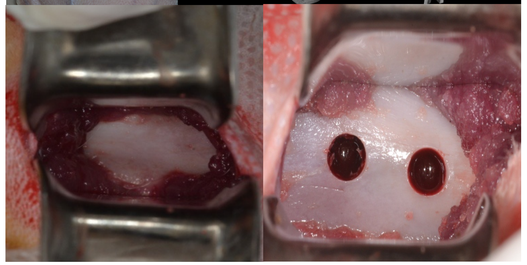


Day 0

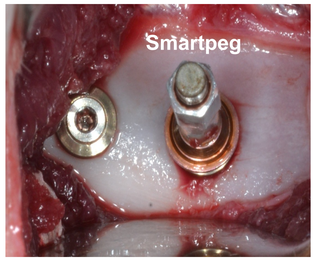
Baseline







Insertion torque & Implant stability quotient (ISQ)





Osstell®

Day 7

Euthanasia

Blood collection

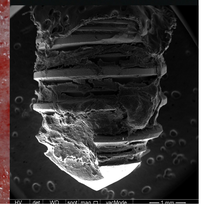
Removal torque



torque wrench





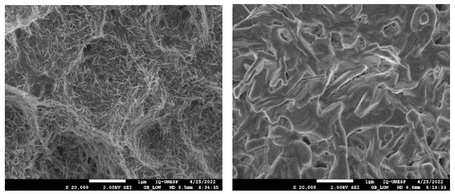


Implants Removed:
- **EDS (X-ray)**
- **Tissue decalcified with EDTA 7%:** for descriptive histology (slides stained with H&E)

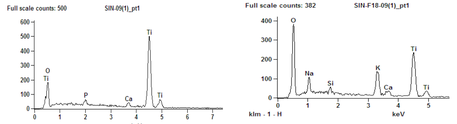
Results

Physical-chemical properties of the surface

Scanning electron microscopy



Energy dispersive x-ray



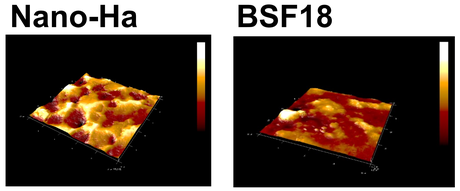
Wettability



Groups	CAº
Nano-HA	49.54±3.74
BSF18	26.04±10.0*

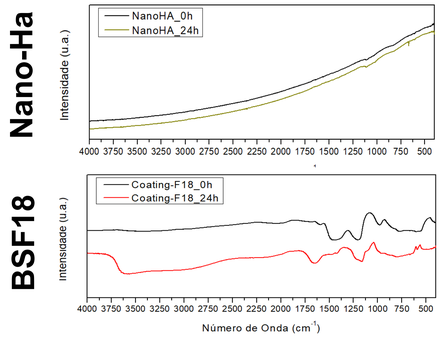
*Significant differences ($p<0.05$). Kruskal-Wallis $p<0.0219$

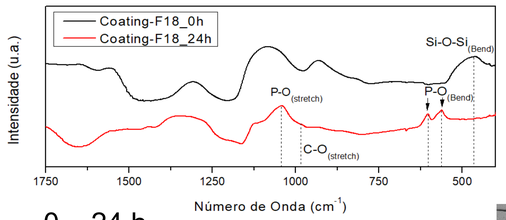
Roughness AFM



Groups	Ra (nm)
Nano-HA	200.6±59.84
BSF18	114.0±53.43

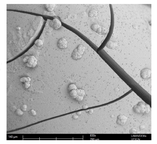
Bioactivity Assay





0 – 24 h

Formation of HCA layer



Biochemistry analysis

Systemic conditions

Weight (kg)

	Hiper		Normo	
Period	kg	SD	kg	SD
Baseline	4.103	265.42	4.056	265.16
7 days	3.251	136.12	3.738	332.46

t test

Glucose Levels (mg/dL)

	Hiper		Normo	
Period	mg/dL	SD	mg/dL	SD
Baseline	131.87	27.13	133.0	15.54
3 days	433.87*	54.96	116.625	9.78
7 days	415.66*	79.53	105.87	9.38

* Significant difference $p<0.05$; t test

Hemoglobin A1C, HbA1c (%)

Quo-Lab® analyzer

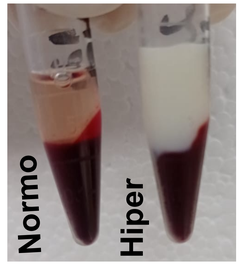
Hyperglycemic rabbit: 5,7 ± 0.8%

Normoglycemic rabbit: > 3.8%

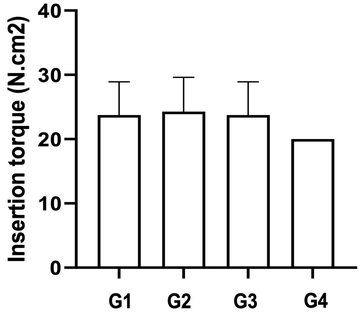
Comparable values between groups:

Cholesterol
Triglycerides
Creatinine
Urea
Alkaline Phosphatase

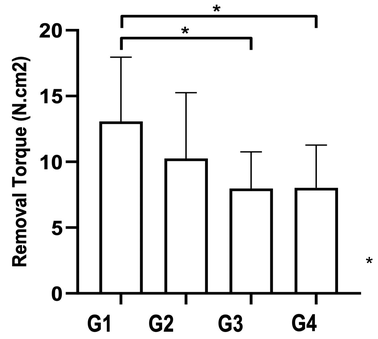
Impact of glycemic condition



Insertion torque and removal torque

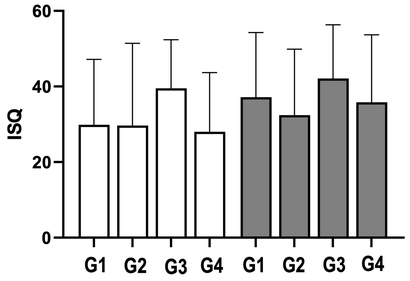


p>0.05; One-way; ANOVA; post-hoc Tukey



* p<0.05; One-way; ANOVA; post-hoc Tukey

Implant stability quotient

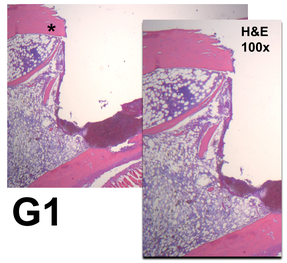


p>0.05; One-way; ANOVA; post-hoc Tukey

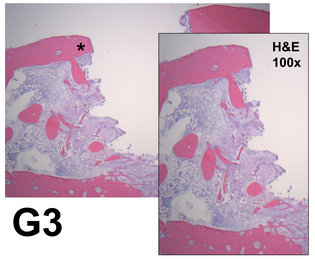
Results

Descriptive histological analysis

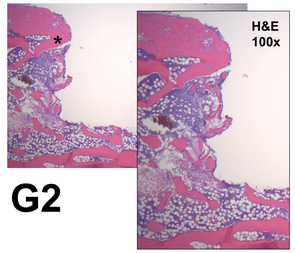
DIASTAR optical microscope (Leica)



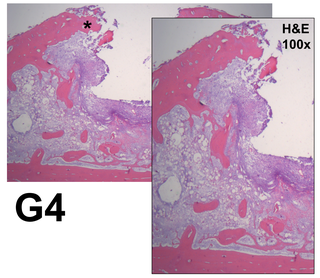
G1



G3



G2



G4

Formation of **new bone**

-

Trabecular aspect: osteocytes, immature mineralized matrix without organization in the form of concentric lamellae and active osteoblasts.

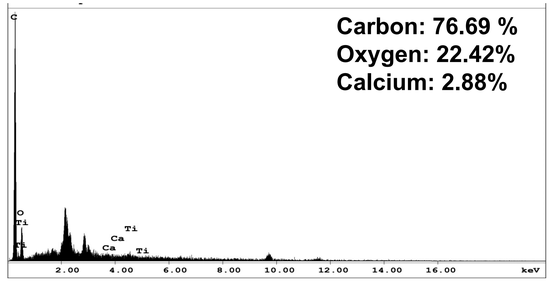
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Organization of the formation of Harvesian channels and presence of medullary tissue.

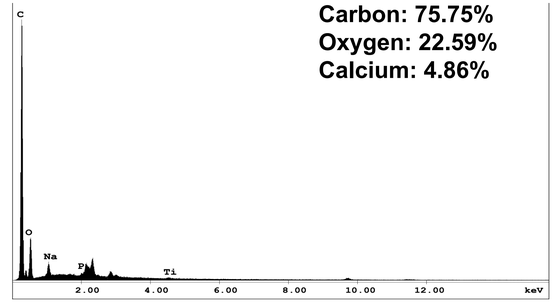


Energy dispersive x-ray / Residual Bone into threads

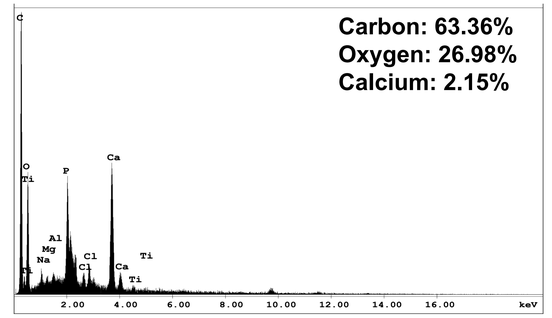
G1



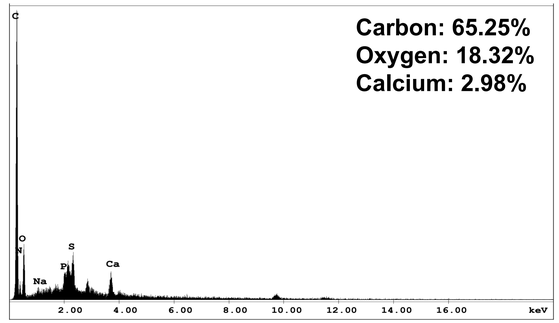
G3



G2



G4



Conclusions

- Clinical Implications (bone quality and systemic condition).
- The removal force required to disrupt osseointegration is surface-dependent and that hyperglycemic conditions could influence the mechanical retention of implants.
- Nanohydroxyapatite and bioactive glass biofunctionalized into nanohydroxyapatite implants can present promising biomechanical results and could be relevant to compensate for impaired bone healing in diabetic and healthy conditions.

Acknowledgements

The Sao Paulo Research Foundation (FAPESP) n. 2013/07793-6; n. 2021/00632-3; n. 2021/14557-3

Center for Research Technology and Education in Vitreous Materials, Sao Carlos, Brazil

SIN Implants, Sao Paulo, Brazil