VOLUME 8 | Issue 1 | April 2024 | ISSN 2209-7627

The Australian Journal of Periodontology and Implant Dentistry Limited

The Official Journal of the Australian Society of Periodontology and the Australasian Osseointegration Society

IN THIS ISSUE

Australasian Osseointegration Society limited

www.ajpid.org.au

medipac®
dental surgery

Trusted by Surgeons Worldwide

surgical sutures

MADE IN GREECE

Distributed by
Geistlich

ABSORBABLE SUTURES
MONOFAST

SYNTHETIC MONOFILAMENT SUTURES MADE FROM A COPOLYMER OF POLYGLYCOLIC ACID AND POLYCAPROLACTONE (PGCL).

NON-ABSORBABLE SUTURES
PROFIMED PTFE

SYNTHETIC MONOFILAMENT SUTURES MADE FROM POLYTETRAFLUOROETHYLENE (PTFE) POLYMER.

For more details please contact our friendly customer service on 1800 776 326 or your local **Geistlich Product Specialist.**

VOLUME 8 | Issue 1 | April 2024

Contents

How to reach us:
www.ajpid.org.au

Paper submission & letters to the editor
editor@ajpid.org.au

Journal annual subscription (for non-members)
admin@ajpid.org.au

ASP Membership enquiries
contact@asp.asn.au
www.asp.asn.au

AOS Membership enquiries
info@aos.org.au
www.aos.org.au

Journal enquiries
admin@ajpid.org.au

Journal Compilation
Lisa Sullivan

Submissions welcome!

Australian Journal of Periodontology and Implant Dentistry aims to promote the field of *Periodontics and Implant Dentistry* through clinical papers, original research, review articles, case reports and other correspondence that the Editor thinks appropriate to print. Submissions of articles covering these areas are welcomed. See website for submission guidelines http://www.ajpid.org.au/

If the reported research involves either human or animal experimentation then the authors must indicate that the ethical guidelines of the Australian National Health and Medical Research Council or the Declaration of Helsinki have been applied. If the research involves human subjects then the authors must state that informed consent was obtained.

Material is received on the understanding that it may be subject to Editorial revision and that, on acceptance, becomes the property of the Australian Journal of Periodontology and Implant Dentistry. All expressions of opinion or statements of supposed facts are those of the authors and are not to be regarded as the views of the ASP/AOS or Editorial Board of Australian Journal of Periodontology and Implant Dentistry.

Digital Subscription

All members of the Australian Society of Periodontology and the Australasian Osseointegration Society will receive two publications per year as part of their membership.

The annual subscription for 2024 will be $68.00 plus GST.

Order queries should be sent to the AJPID Administrator Kayla Ashkar: admin@ajpid.org.au

Editor's Notes

Welcome

It is with great pleasure to present the Editorial Report for the first quarter of 2024. Over the past two years, our journal has continued to flourish, thanks to the dedication and hard work of our contributors, reviewers, and editorial team. As reported in the last issue, the journal implemented a peer review process to improve the quality of articles, and this was the first time all the articles underwent this review process. We are immensely grateful to our dedicated reviewers who have generously contributed their time and expertise to this process. Your insightful feedback and constructive criticism have been instrumental in shaping the content of our journal and maintaining its high standards.

For this journal issue, we have published three articles. The first article by *Dr Ruchi Agarwal* (University of Melbourne), is titled *'A comparison on different bone graft materials used for GTR /GBR procedures in Australia: A narrative review.'* To date, there are numerous TGA-approved regenerative materials used for GTR and GBR in Australia. This narrative review discusses and compares commercially available regenerative materials in Australia for their regenerative effectiveness based on the existing literature.

The second article, by Dr. Alan Zhu (University of Queensland), is another narrative review focusing on the clinical indications and long-term outcomes of SLActive surfaced implants. While the effects of hydrophilic moderately rough (SLActive) surfaced implants on early bone formation and osseointegration have been well-documented in the literature, evidence for their long-term clinical outcomes is scarce.

The last article by *Dr Faisa Azzahra, Dr Monisha Morshed, and Dr Tina Kamarudin* (University of Western Australia) explores the potential of certain bone resorptive biomarkers, NTX-I and TRAP5b as diagnostic and prognostic tools in peri-implantitis. The authors also discuss their relevance in the diagnosis of periodontitis and other non-oral metabolic bone diseases.

I find all the reviews in this issue to be very informative and helpful in understanding interesting topics in periodontology and implant dentistry. I hope you enjoy reading them.

In closing, I'd like to thank all the contributors, reviewers, and editorial team for their continued support and dedication. we look forward to your continued partnership in the years to come.

Regards,

A/Prof Ryan Lee
Editor-in-chief

President's Notes

I am pleased to present the President's Report for the first quarter of 2024. The highlight of this report is the upcoming ASP/AOS/APS Biennial Conference in September 2024. All preparations and organization are in full swing, and we have been very successful with sponsorships.

This conference promises to be an exceptional event, featuring a packed program with many world-leading international and local speakers covering a wide range of topics in Periodontics, Prosthodontics, and Implant Dentistry. With such a diverse program, there will be something for everyone, including hygienists and oral therapists.

The conference program will include keynote lectures, multiple concurrent sessions, panel discussions, and hands-on workshops, providing attendees with invaluable insights and practical skills that they can apply in their everyday clinical practice. I am confident that this conference will be a highlight of the year for all attendees, offering a unique opportunity to engage with peers, network with experts, and stay updated on the latest advancements in our field.

In addition to the scientific program, there will be some amazing social events planned for the attendees and their families. This includes a roof top Cocktail Party on the opening night, as well as a Gala Dinner at Sea World, Gold Coast, offering a truly memorable experience for all attendees.

I encourage all our members (ASP, AOS and APS) to take advantage of this exceptional learning and networking opportunity by participating in the conference. Early-bird registration is already opened and I look forward to seeing you all at the conference.

In closing, I would like to congratulate all the authors who have published in this issue of the journal and hope everyone enjoys the reading.

Sincerely,

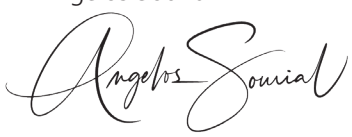
A/Prof Ryan Lee
ASP Federal President

Another year has passed and we are now well into 2024. I hope that you were able to enjoy a refreshing break over the new year period. We are now almost 6 months away from Australia's biggest implant conference of the year- the combined AOS, ASP, APS biennial conference, which will be held in the Gold Coast between the 19th-21st September 2024 at the Gold Coast Convention Centre. We have arranged several high calibre keynote speakers namely Joseph Kan, Purnima Kumar and Frank Renouard. We've also been able to attract several sponsored and local speakers to enrich the scientific program. Early bird registrations are now open and I would encourage you to make the most of the hands-on pre-congress workshops that will be running on the 18th of September.

Congratulations go to all the authors that have been published in the current journal and a big thank you also goes to the editors and administrators for their tireless efforts in making this publication possible.

Best wishes to all who just celebrated Easter, are about to celebrate Eid and Passover and a happy year of the dragon to those who celebrated the lunar new year.

Dr Angelos Sourial



AOS Federal President

VOLUME 8 | Issue 1 | April 2024

The Australian Journal of Periodontology and Implant Dentistry

A Comparison on Different Bone Graft Materials (Allografts vs Xenografts vs Synthetic Materials) Used for GTR/GBR Procedures in Australia: A Narrative Review

Ruchi Agarwal
*Department of Periodontics, Melbourne Dental School, The University of Melbourne, Carlton, Victoria

Abstract:

The ideal aim of periodontal therapy is to regenerate the tissues destroyed during periodontitis. Bone replacement grafts are used in GTR/GBR procedures where additional support and space-making requirements are essential and commonly used in managing periodontal defects, peri-implant defects, bone augmentation, and ridge preservation procedures. Regenerative materials need TGA approval for their usage in clinical practice in Australia. This paper will discuss and compare the bone replacement graft materials available in Australia and their regenerative effectiveness in GTR/GBR procedures.

Keywords: Guided tissue regeneration, Guided bone regeneration, bone grafts, TGA (Therapeutic Guidelines Australia), Australia.

Abbreviations and acronyms: GTR (Guided tissue regeneration), GBR (Guided bone regeneration), b-TCP (tricalcium phosphate), DBBM (deproteinized bovine bone minerals); DFDBA (demineralized freeze-dried bone allograft); ePTFE (expanded polytetrafluoroethylene membranes); FDBA (freeze-dried bone allograft); FFB (fresh frozen bone); HA (hydroxyapatite); LJE (long junctional epithelial); SBC (Straumann Bone Ceramic); TGA (Therapeutic Goods Administration), ARTG (TGA's Australian Register of Therapeutic Goods).

INTRODUCTION

Periodontitis is a chronic multifactorial inflammatory disease associated with dysbiotic plaque biofilm and results in progressive loss of periodontal attachment apparatus in a susceptible host if allowed to progress and not treated on time (1). It can lead to alveolar bone resorption and defect, attachment loss, and potential tooth loss (2). Over many years it was believed that management of periodontal disease could be achieved by biofilm control, which invariably results in repair than regeneration in most scenarios (3). The ideal aim of periodontal treatment is regenerating the lost periodontium in a predictable and reproducible manner. Efforts have been continuously directed at predictably achieving periodontal regeneration to improve the clinical outcomes and success of the therapy. The biomaterials that are used for this purpose are bone grafts/substitutes that replace the lost part of alveolar bone, barriers (membrane) that cover the alveolar bone defect, protecting it from epithelial down growth; and biologics with biological activity for true periodontal tissue engineering (4). Melcher reported that the growth rate of cells and selective repopulation of cells decide the fate of healing and regeneration. Epithelial cells have the highest turnover and rapidly migrate apically before periodontal ligament cells or osteoblasts can migrate and repopulate, adversely affecting regeneration (5). This led to the evolution of the GTR (guided tissue regeneration) procedure using a barrier membrane, which has proven to effectively prevent epithelial and gingival CT cells from migrating into the blood clot around the root surface(6). With our current understanding, we now understand that it's not only the repopulating cells which decides the fate but several other factors as the surgical technique, favourable space available, stability of clot etc. The GTR procedure aims to facilitate regeneration in periodontal defects (intrabony defects, furcation defects) and GBR procedure aims to regenerate bone around implants and during ridge preservation procedures. This paper will compare bone grafts as allografts, Xenografts, and synthetic materials(alloplasts)

available in Australia (TGA approved) and their usage in GTR/GBR procedures.

RATIONALE BEHIND USING BONE GRAFTS IN GTR/GBR PROCEDURES

AAP (Glossary of Periodontal Terms, 1992) (7) has defined Regeneration as the "reproduction or reconstruction of a lost/ injured tissue such that the architecture and function of the lost/injured tissues are completely restored." Periodontal regeneration includes the regeneration of the periodontal ligament (PDL), cementum with inserting collagen fibres from the new PDL, and alveolar bone (8). This is different from "new attachment," which only involves the formation of new cementum with attaching fibers and not a complete periodontal regeneration. During regeneration, progenitor cells must migrate, proliferate, and get organized into respective tissues with functional capacity. This involves the migration of PDL cells to denuded root surfaces and get organized and attached to newly formed cementum, and progenitor bone cells should also achieve the same to form a new bone. This regeneration can be assessed clinically and radiographically however whether it's a true regeneration can only be verified and visualized histologically (9). To achieve the additional support and space-making requirements, regenerative procedures can be combined with a bone replacement graft material during the management of periodontal intrabony defects, ridge preservation, site augmentation by simultaneous or staged grafting procedures(in Implant dentistry), management of peri-implant defects and in sinus augmentation. Bone grafts have regenerative capacity due to their osteoconduction, osteoinduction, and osteogenesis properties. Osteoinductive materials harbor proteins or growth factors which promote the proliferation and differentiation of progenitor cells from the fibrin clot and native bone to promote regeneration and form new bone. Osteogenic materials contain tissues or cells from which bone can be formed. Osteoconduction means that bone grows on a surface. Osteoconductive materials provide a scaffold, maintain space and stabilise the coagulum to enable the growth of new bone and, eventually replacement. With osteoconductive materials, cells are primarily derived from the blood vessels of the surrounding walls of defects and, therefore, multiple-walled defects may enable greater bone formation as a function of the greater proportion of vessels. Bone grafts based on their source are classified into autograft, allograft, xenograft and alloplastic/ synthetic bone grafts. These biomaterials have all been studied for their regenerative capacity in GBR/GTR procedures, both as stand-alone therapies and in combination with barriers and/or biologics. The ideal property of a bone graft material include biocompatibility, safety, non-allergenic, non-toxic, and should not have any risk of disease transmission. It should also exhibit space-maintaining properties (allowing for ingrowth of cells and blood vessels), good clinical handling characteristics, and similar resorption rate, composition, and particle size to human bone (3).

TYPES OF BONE GRAFTS AVAILABLE (BASED ON THE SOURCE):

Autografts are obtained from the same individual. Transplantation of autogenous bone brings progenitor cells (with osteogenic potential) and bone-stimulating growth factors to the recipient site. The degree of cells and growth factors is variable depending on the individuals, and site variation, with the patient's age, systemic health, and donor location having a significant influence. Autogenous bone grafts have been shown to have the ideal particle size and space for vascular ingrowth. Common sites intra-orally where autografts can be harvested include the anterior nasal spine, zygoma, canine fossa, tuberosity, and the area adjacent to the surgical site. Their major disadvantages are the morbidity and risks associated with a second surgical site. Other considerations include limitations of graft size/ volume at donor sites and size of bone particles. Smaller particles are resorbed more quickly, which may result in less bone regeneration over time.

Allografts are derived from another member of the same species. Commonly stored in bone banks, it comes in three main forms, fresh frozen bone (FFB), freeze-dried bone allograft (FDBA), and demineralised freeze-dried bone allograft (DFDBA). Freeze-drying of bone is done to reduce the chances of immunologic reactions and disease transmission. Allografts come in either block or particulate form and contain proteins (bone morphogenic proteins) that can stimulate bone formation and demonstrate osteoconductive and osteoinductive properties. The products that are available in Australia are *MinerOss® Puros® Particulate Allograft, Oravance, Milled bone ultra fine (0.5-1mm) and cortical segment.*

Xenografts originate from a species other than that in which they are to be placed in. Generally, in dentistry, they are derived from coral, cows, horses, and pigs. They typically

have an osteoconductive role, acting as a scaffold for new bone growth. Deproteinised bovine bone minerals (DBMMs) most commonly available in Australia as Bio-oss and Bio-Oss collagen (10% porcine collagen and 90% DBBM) from Geistlich, Wolhussen, Switzerland. Examples of others are Endobon® (Biomet 3i), and MinerOss XP (Biohorizon).

Alloplastic Grafts/Synthetic materials are synthetic or inorganic bone substitutes such as calcium, phosphate, or silica-based glass. Such components include tricalcium phosphate (β-TCP), biphasic calcium phosphate and hydroxyapatite (HA) or silica-based glasses (Perioglass® or Biogran®), or polymers (Bioplant®). No donor site is required, and subsequently, no limitation in the amount able to be produced. Alloplastic grafts are osteoconductive in nature. Calcium phosphate ceramics include β-TCP (Cerasorb®, KSI-Tricalciumphosphate®, BioResorb®, Ossaplast®, Ceros®, Rootreplica®, Calc-i-Oss®, Osteon®, ChronOS®) and hydroxyapatite (Nanobone®, Durapetite®, PerioGraf®) are some of the examples. Straumann Bone ceramic (a biphasic calcium phosphate) is available in Australia through Straumann Ag, Basel, Switzerland. Others available are silica-based glasses (Perioglass® or Biogran®), or polymers (Bioplant®) HTR, and tricalcium phosphate (β-TCP) (Osteon).

COMMERCIALLY AVAILABLE BONE GRAFT MATERIALS IN AUSTRALIA (FOR USE IN GBR/GTR PROCEDURES)

To allow any regenerative material to be commercially available and to be used in clinical practice in Australia, they need to be TGA (Therapeutic Goods Administration) approved. After passing through the strict criteria and multistage testing on products, they are introduced to the Australian market.

Below table summarises different types of *bone graft materials and membranes* and *commercial brands available in Australia (in Bold)* (available since early 2000) (3)

Bone replacement graft materials added to Australia in last 10-15years are (34)-

MinerOss®, Puros® Particulate Allograft, Oravance, Milled bone, Endobon® (Biomet 3i), MinerOss X, XP, MinerOss X Plug, EthOss®, MIS BONDBONE™,4BONE™ BCH, BVital GenOSS Granules BS-G005(MIS), NovaBone® Dental Putty, R.T.R.+ 80/20, R.T.R.+ 40/60, OSSIX™ Bone (Alloplastic bone graft + Biologics) Emdogain Plus.

Table 1: Different types of *bone graft materials* and *commercial brands available in Australia (since 2003)*

Autogenous	Allografts	Xenografts	Alloplasts or synthetic grafts
	• Fresh frozen bone (FFB) • Freeze-dried bone allograft (FDBA) • Demineralized freeze-dried bone allograft (DFBDA) • **Biohorizons**	• Bovine – **Bio-Oss** – OsteoGraf – Navigraft – **Bio-Oss with Collagen** – PepGen P-15 – Endobon • Equine – BioGen • Coral hydroxyapatite – Pro Osteon – Interpore 500 (HA + CC) – Biocoral • Algae hydroxyapatite – Frios – Algipore – C-Graft	• β-TricalciumPhosphate: • Cerasorb • KSI-Tricalciumphosphate • BioResorb • Ossaplast • Ceros • Rootreplica • Calc-i-Oss • **Osteon** • Hydroxyapatite • Nanobone • β-TCP & HA • **Straumann Bone Ceramic** • Bioactive Glasses • **PerioGlas** • **Biogran** • Filler Bone • Polymers • **Bioplant HTR**

Table1 (Source: Darby, I.ADJ 2011) (3)

Table 2: Different types of membranes and commercial brands available in Australia (since 2003)

- Non-resorbable
  - PTFE
    - TefGen-FD, BioBarrier NP
  - ePTFE
    - **GoreTex**
  - Titanium-reinforced ePFTE
    - **GoreTex**
  - Cellulose
    - Millipore
  - Rubberdam
- Resorbable
  - Collagen
    - **Bio-Gide**
    - **Ossix**
    - **BioMend**
  - Polylactic
    - Guidor
  - Polylactic/polyglycolic
    - Ethisorb
    - **Vicryl**
    - Inion
  - PL, PG & Trimethylcarbonate
    - **Gore Resolut**
  - PG & TMC
    - **Gore Resolut Adapt**
  - Acellular Dermal Allograft
    - **Alloderm**
  - Polyethylene glycol
    - Membragel

Table 2 (Source: Darby, I.ADJ 2011) (3)

Allograft (34):

The allografts are usually obtained from tissue extracted during orthopaedic surgeries such as hip replacement surgery or from deceased donors (long bones). Donor tissue has to pass through strict criteria before acceptance and go through multistage process under strict standards of the TGA to meet the strict guidelines.

- ***MinerOss® (TGA approved in 2004)**, a mixture of allograft mineralised cortical and cancellous chips, was added to the Australian market by **BioHorizons**. They need to go through TGA special access scheme for usage.*

(Source: biohorizons.com/products/biologics)

- ***Puros® Particulate Allograft available through ZimVie (TGA approved since mid-2005-2006)** are available in cortical particulate, cortico-cancellous particulate, and cancellous particulate forms. They are osteoconductive and allow the ingrowth of vascular and cellular connective tissue.*

(Source: zimvie.com/en/dental/biomaterial)

- *Australian Biotechnologies Pty Ltd (Sydney) offers a full range of allografts obtained from human donors and listed under ARTG (TGA's Australian Register of Therapeutic Goods), available through **Henry Schein Halas**.*

***Oravance (TGA approved in 2017)** -bone and collagen matrix, freeze-dried, and available in cortico-cancellous bone granules, cortical block, cortico-cancellous block, sheet, plate through **Henry Schein**. They are available in different forms, as-*

- *ORAVANCE CorticoCancellous Bone Granules 0.5cc,2cc,1.0cc, Granule Size: 500µm–1000µm.*
- *ORAVANCE Cortical Sheet 25mm,35mm*
- *ORAVANCE Pure Cancellous GRANULES 500um -1000um*
- *ORAVANCE Cortical Block 7mm x 11mm x 10mm*
- *ORAVANCE Cortico-Cancellous Block- 7mm x 11mm x 20mm*

(Source: henryschein.com.au/oral-surgery/grafting-materials)

- **Milled bone ultra fine (0.5-1mm) and cortical segment, ARTG ID 229915 - Recently added (in 2021) Australian Allograft company (Pluslife Allografts, Western Australia)** *-available for dental and oral and maxillofacial use. They are osteoconductive and provide a scaffold for bony ingrowth.*

(Source: australianallografts.com.au/allografts)

Xenografts (34):

- **Bio-Oss and Bio- Oss collagen, ARTG ID 229994**

Deproteinised bovine bone minerals (DBMMs) are most commonly available in Australia (from Geistlich, Wolhussen, Switzerland) as **Bio-Oss and Bio- Oss collagen** (10% porcine collagen, and 90% DBBM) available in 50mg,100mg,150mg,250mg sizes. Bio-Oss is available in small (0.25 – 1 mm) in different sizes 0.25 g ~ 0.5 cc,0.5 g ~ 1 cc,1 g ~ 2 cc,2 g ~ 4 cc or large granules (1 – 2 mm). Bio-Oss® products are derived from cows that are raised in Victoria, Australia. Bones of euthanised animals are transported to Switzerland for chemical and thermal processing. Thermal processing ensures the removal of all organic components without destroying the natural tissue architecture. Calcium: phosphorous ratio, porosity, crystallite size and inner surface area of Bio-Oss® closely resembles human cancellous bone. The product is considered extremely safe, with no reports of disease transmission.

(Source: geistlich.com.au/dental-professionals/bone-substitutes/geistlich-bio-oss)

(Source: geistlich.com.au/dental-professionals/bone-substitutes/bio-oss-collagen)

- **Endobon® (available through Biomet 3i/ Zimvie), ARTG: 120288** -Deproteinized Bovine derived HA, non-resorbable material, osteoconductive due to interconnecting micro and macro pores, available in small (500-1000microm) granules and large granules (1000-2000microm)

EndoBon

(Source: zimvie.com/en/dental/biomaterial-solutions/endobon-xenograft-particulate-gl.html)

- **MinerOss X, XP (available through Biohorizon) - TGA approved in 2018, ARTG ID 299220.**

(Anorganic porcine bone mineral matrix with osteoconductive properties maintains adequate space for new-forming bone due to its highly porous nature.

MinerOss XP

(Source: henryschein.com.au/oral-surgery/grafting-materials/mineross-xp)

- **MinerOss X Plug**- is bovine-derived and composed of 80% cancellous particulate and 20% (Type I) collagen. It supports the formation and ingrowth of new bone at the implantation site.

MinerOss X Plug
(Source: henryschein.com.au/search?ProductSearch=graft/mineross Xplug)

Alloplastic Grafts (34):

- **Straumann Bone ceramic, ARTG ID 194429 (in 2012)**- is a biphasic calcium phosphate available in Australia through Straumann Ag, Basel, Switzerland. It is a 60:40 mixture of HA and B-TCP. Calcium and Phosphate aid in space provision, and HA maintains the scaffold.

(Source: https://shop.straumann.com/au/en_au/Biomaterials/Bone-Subsitutes/c/cat_stmn_bonesubs)

- **Straumann® XenoFlex (bovine-derived,50-500mg) and Cerabone® Granules (bovine-derived,0.5-2mm)** are new additions.
- ***EthOss®, ARTG ID 299917 (since 2018)-*** *Bi-phasic (beta tri calcium phosphate and calcium sulphate) material. TGA approved material and available through* ***EthOss*** *Regeration Ltd.*

COMPOSITION	65% [illegible] calcium phosphate, (βTCP) $Ca_3(PO_4)_2$, 35% calcium sulfate $CaSO_4$
RESORPTION TIME	Typically 90% new bone at 12 weeks. Full resorption usually over following 6-12 months.
MIXING AGENT	Standard sterile saline (0.9% Sodium Chloride) only
RECOMMENDED RE-ENTRY TIME	12 weeks
UNITS AVAILABLE	1 x 0.5cc, 1 x 1cc, 1 x 0.25cc

(Source: medident.com.au/brands/ethoss)

- ***MIS BONDBONE™, ARTG ID 189584 (since 2011)***

(100% pure biphasic calcium sulfate) ***through Moredent***.

- ***4BONE™ BCH*** *– contains HA (60%) and TCP (40%),* ***through Moredent***.
- ***BVital GenOSS Granules BS-G005(MIS), ARTG ID 376529 (2021), through Moredent***

Osteoconductive, porous, anorganic porcine-derived cancellous bone. Its carbonate apatite is similar to natural human bone.

Bondbone ***Bvital GenOSS Granules BS-G005***

(Source: moredent.com.au/search?q=bone+graft)

- ***NovaBone® Dental Putty, ARTG ID 242772 (2015)***

It is composed of calcium phosphosilicate (CPS) particles along with a polyethylene glycol and glycerine binder and is available through Device Technologies Australia Pty Ltd. It resorbs completely.

(Source: https://www.device.com.au/our-brands/NovaBone)

- ***R.T.R.+ 80/20 ARTG ID 373571 (2021)***

(80% β-Tricalcium Phosphate / 20% Hydroxyapatite) and ***R.T.R.+ 40/60, ARTG ID 373570 (2021)*** *(40% β-Tricalcium Phosphate / 60% Hydroxyapatite) through* ***Henry Shein****.*

(Source: henryschein.com.au/oral-surgery/grafting-materials/rtr-80-20-synthetic-bone-syringe)

- ***Osteon II*** *available through* ***Minimax****. 100% Synthetic bone grafting material. HA scaffold with β-TCP (HA 30% + β-TCP 70%)—resorbable bone grafting material ideal for socket preservation and implant sites.*

(Source: https://www.minimaximplant.com.au/bone-regeneration/osteon2/)

- ***OSSIX™ Bone (Dentsply Sirona) ARTG ID 380303.****- an ossifying collagen sponge, has cross-linked collagen with hydroxylapatite crystals. Aids in space provision for vascularization, cellular proliferation, and maturation. It can be used without a membrane in some extraction socket grafting procedures. Available in 5x5x5mm (0.125cc), 5x5x10mm (0.25cc), 5x10x10mm (0.5cc). Others are* ***OSSIX™ plus, OSSIX™ Volumax.***

Ossix Plus

Ossix Bone

Ossix Volumax

(Source: dentsplysirona.com/enau/shop/brands/ossix)

DO THESE BONE REPLACEMENT GRAFTS REALLY AID IN REGENERATION? AND HOW DO THEY DIFFER?

Various studies have been conducted to assess the efficacy of different bone graft materials in GTR/GBR procedures. There is a heterogeneity in the literature and the information available is too vast to be all included in the scope of this paper. Below tables (3,4) summarises some of the available evidence as outlined by different research to support the use of available bone graft materials with their outcomes in different periodontal and peri-implant procedures.

PERIODONTAL OUTCOMES

The use of porous hydroxyapatite cements for periodontal regeneration has shown mixed results, few in favour (24) and others (using HTR polymer) failed to prove any benefit (25).

Table 3: PERIODONTAL OUTCOMES

Authors	Rationale	Study design/defect type/biomaterials used		Main findings
Reynolds MA et al 2003 (10)	aimed to access the efficacy of bone replacement grafts in clinical improvements as compared to surgical debridement alone	systematic review: medline and Embase were searched from 1966,1974 to 2002 for RCT studies. 49 controlled studies provided clinical outcome on intrabony defect, 17 studies for treatment of furcation defects.	Various BRG materials were studied in included studies - eg allografts (DFDBA), autogenous graft, calcium phosphate (HA),xenografts	usage of bone grafts results in pocket depth reduction, increase in clinical attachment level, reduced crestal bone loss, and increase in bone levels in comparison to open flap debridement (OFD) procedures. No differences in clinical outcome could be observed between particulate bone allograft and calcium phosphate (hydroxyapatite) ceramic graft material. When combined with barrier membranes, they found that there was an increase clinical attachment level and probing depth reduction compared to graft alone. In relation to furcation defects, some positive clinical benefits were noted in Cl II furcations.
Murphy KG et al 2003 (11)	aimed to access the efficacy of GTR in periodontal osseous defects in clinical improvements as compared to surgical controls	systematic review: medline and cochrane oral health group register were searched upto 2002. studies with at least 6months follow-up included.	Materials used were- expanded polytetrafluoroethylene (ePTFE) with and without demineralised freeze-dried bone allograft (DFDBA), polylactic acid, polyglactin 910, polyglycolic acid, human collagen, bovine collagen with and without DFDBA, cellulose plus hydroxyapatite, and pericardium plus bovine porous bone mineral. Antibiotics was used in some studies.	bone replacement grafts with GTR were significantly better in outcomes for intrabony and Cl II mandibular furcation defects and intrabony defects as compared to OFD therapies. No statistically significant differences between different types of barriers were detected.
Jepsen S et al 2002 (12)	aimed to access the efficacy of GTR in furcation defects in clinical improvements as compared to surgical debridement	systematic review: electronic database, hand searched journals and contact with experts were included.studies with at least 6months follow-up included.	Materials used were- expanded polytetrafluoroethylene (ePTFE),synthetic membrane (biobrane),resorbable mebrane (collistat), (bioMend)	GTR were consistently better in outcomes for reducing open horizontal furcation depth,horizontal and vertical attachment levels and ppd for mandibular and maxillary Cl II furcation defects. Due to heterogeneity of data authors pointed out limited general conclusions that could be drawn, indicated need for future studies.
Richardson, C. R et al 1999 (13)	The purpose of the study was to compare Bio-Oss to DFDBA in intrabony defects.	17 healthy patients,30 defects were included. Intraosseous defect that >3mm were included	bovine derived xenograft (BDX) Bio-Oss®, demineralized freeze dried bone allograft (DFDBA)	a statistically significant improvement in PD and AL for both materials at 6 months in 26 defects. Osseous measurements showed bone fill of 2.4 mm (46.8%) for the DFDBA group vs 3.0 mm (55.8%) for the BDX group. Defect resolution was 59.4% for the DFDBA group vs 77.6% for the BDX group. No statistical difference between the 2 materials in all measurements were found statistically.

Authors	Rationale	Study design/defect type/biomaterials used		Main findings
Clergeau et al 1996 (14)	Aimed to assess the regenerative potential of anorganic bone plus collagen (Bio-Oss Collagen®) in an experimental periodontitis model in 8 beagle dogs	8 female beagle dogs	anorganic bone plus collagen (Bio-Oss Collagen®)	by 36 weeks, significant bone regeneration with a combination of both immature and mature bone tissue was observed. Regions of vascularisation were also noted, which confirmed the vitality of the newly deposited tissue. As tissue matured, a clear periodontal ligament space could be observed, and particles became progressively integrated into the native bone
Stavropoulos, A 2010 (15)	Clinical and histologic evaluation of granular Beta-tricalcium phosphate for the treatment of human intrabony periodontal defects	intrabony defects in five patients		PPD was found to be reduced by a mean of 6.2mm and the mean CAL gain was 5.0mm. Histologically, the formation of new cementum with inserting periodontal ligament fibres was observed to a limited degree of 1.2-3.0mm. In most biopsies, particles of β-TCP were embedded within connective tissue, and new bone and cementum were only occasionally identified around β-TCP particles. It was concluded that, despite clinical improvement, β-TCP did not result in true periodontal regeneration
Rabalais ML Jr,1981(16) Meffert, R. M 1985 (17)	Dense hydroxyapatite ceramic was compared to OFD alone for infrabony defects	8-12 patients were assessed		upon 6 months of reentry, it was found that dense hydroxyapatite ceramic resulted in 40-60% complete bone infill, depending on the depth of the defect. The authors concluded that dense hydroxyapatite ceramic offered a clinical benefit in treating infrabony periodontal defects
Yukna, Rb 1985 (18)	Aimed to evaluate the efficacy of durapatite ceramic as an alloplastic implant in periodontal osseous defects	152 defects were treated with hydroxylapatite (HA) grafts were compared to those from 111defects treated by surgical debridement alone (DEBR)		58% of the HA-grafted defects were found to have a positive (≥50% defect fill) hard tissue response compared to 30% for DEBR
Brown, G. D 1998 (19)	compared the grafting with hydroxyapatite cement and DFDBA to OFD alone in treating intrabony defects			HA was inferior to both DFDBA and OFD for all clinical parameters. Histologically resulted in healing with a long junctional epithelium rather than periodontal regeneration
Barnett et al (20)	compared the use of FDBA to PHA in the treatment of intrabony periodontal defects	19 pairs of intraosseous defects were grafted in 7 patients. One defect of each pair was implanted with FDBA, the other with granular porous hydroxylapatite.		FDBA was found to have enhanced reparative potential as compared to granular porous hydroxylapatite in the treatment of periodontal defects in humans

Authors	Rationale	Study design/defect type/biomaterials used	Main findings
Nery, E. B (21)	compared the use of Straumann Bone Ceramic®, autogenous bone, and OFD in the treatment of infrabony defects over three years		no statistical difference between outcomes in any group
Jensen et al (22)	compared the use of the use of Straumann Bone Ceramic®, β-TCP alone, hydroxyapatite alone and autogenous bone graft	4 standardized bone defects were prepared in 16 minipigs and grafted with autogenous bone chips, HA, HA/TCP (60% : 40%), or TCP	Autograft and TCP resorbed quickly and almost completely over 8 weeks, whereas HA/TCP and HA showed limited degradation over 24 weeks. All defects healed with mature lamellar bone and intimate contact between bone and the remaining graft material was found.
Ong, M. M., (23)	Evaluation of a bioactive glass alloplast in treating periodontal intrabony defects	14 patients, with 2 contralateral sites with >/6mm ppd, radiographic evidence of intrabony defect	Bone graft was superior to OFD clinically but no statistically significant difference between the groups was found.

PERI-IMPLANT OUTCOMES

During the budding years of GBR, barrier membranes (non-resorbable- e-PTFE) alone were used to achieve GBR around implant defects or during a staged/ simultaneous approach. Later, when resorbable membranes were used, bone replacement grafts were found to be necessary with additional benefits to maintain space and prevent membrane collapse. GBR technique is beneficial to overcome hard tissue deficiencies and utilised for bone augmentation procedures prior to Implant placement as staged augmentation, ridge or socket preservation or simultaneous augmentation during implant placement surgery and in the management of peri-implant defects.

The outcome of augmentation depends on the type of defect, operator skills, and materials used. Predictability for horizontal augmentation with autologous bone blocks with or without membrane is better than vertical (3).

CONCLUSION

The materials available in Australia are limited but sufficient enough to provide the best and most successful outcomes for our patients. When choosing the bone graft materials, the clinician must consider and understand the pros and cons of each material in terms of predictability, operator skills, cost, and defect morphology to allow for a predictable and successful outcome. With our growing understanding and advancements, we need further research where bone replacement graft material or combinations could be modified to enhance the osteogenic potential for consistent and predictable regenerative outcomes irrespective of the site or type of defect and to allow them to be the part of our day-to-day practice in Australia, these newer materials or combinations must pass through strict TGA guidelines.

REFERENCES

1. Papapanou, PN, Sanz, M, et al. Periodontitis: Consensus report of Workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Periodontol*. 2018; 89(Suppl 1): S173– S182.

2. D. F. Kinane, P. G. Stathopoulou, and P. N. Papapanou, "Periodontal diseases," *Nature Reviews Disease Primers*, vol. 3,no. 1, p. 17038, 2017.

3. Darby, I. Periodontal materials. *Aust Dent J*, 2011,56: 107-118.

Table 4: PERI-IMPLANT OUTCOMES

Authors	Rationale	Study design/materials	Main findings
Jensen et al 2014(26)	case series to evaluate the efficacy of using autogenous bone chips combined with deproteinized bovine bone mineral (DBBM) and a collagen barrier membrane for contour augmentation around implants	10 patients, followed up for 8 years, 12 biopsies were taken from 14-80 months after implant placement and simultaneous contour augmentation	concluded on histometric analysis that mature bone consisting of parallel-fibered or lamellar bone, with multiple residual DBBM particles identified mostly embedded in bone when exposed implant surfaces were covered with a layer of autogenous bone chips at the base with a layering of DBBM over to cover the basal layer followed by a double layer of collagen membrane over the top.
Gelb DA 1993(27)	Immediate implant surgery with three-year retrospective evaluation of 50 consecutive cases	35 pateints,50 extracted sites. GBR with DFDBA (demineralised freeze dried crushed cancellous bone),e-PTFE membrane or both	Re-entry confirmed 100% thread coverage in all but one implant in the no-wall group treated with DFDBA alone. Histologic evaluation of three cases confirmed viability of the regenerated bone. On follow up, implants (98%) remained osseointegrated and functional.
Zitzmann NU (28)	retrospective study, simultaneous GBR treatment with Bio-Gide + Bio-Oss was studied for 112 Nobel implants (smokers and non-smokers)		GBR was more successful around maxillary implants with 96% defect fill compared to 78% in the mandible with non-significant differences between smokers and non-smokers.
Buser D (29)	Case report		simultaneous GBR technique with use of a resorbable membrane covering a two-layer composite graft (autogenous chips + Bio-Oss) with autogenous graft in contact with implant surface is predictable method for contour augmentation
Chiapasco M (30)	systematic Review		prosthetically guided regeneration, allows for the reconstruction of lost alveolar and soft-tissue contours as well as implant placement in positions to permit prosthetic restorations that are optimal from a functional and esthetic viewpoint
Chen et al (31)	30 immediate transmucosal implants in maxillary anterior extraction sites,30 patients randomly received BioOss,(BioOss and resorbable collagen membrane (BG+M) or no graft (control).		Bio-Oss did not reduce the vertical resorption and both Bio-Oss and Bio-Oss + Bio-Gide groups were successful in reducing the horizontal resorption. There is a risk of mucosal recession and adverse soft tissue esthetics with immediate implant placement.
Bazrafshan N (32)	Retrospective study evaluating success and survival rates of dental implants placed with simultaneous bone augmentation in partially edentulous patients		The mean PPD, BOP, and Plaque index were not statistically significantly different in GBR vs. non-GBR groups two to seven years in function. However, bone loss is significantly less in GBR group 2-7 years after function. The overall success rate was around 90% after 2-7 years in function with the GBR group slightly less than the non-GBR group, but not statistically significant.
Chappuis et al. (33)	Prospective case series, evaluated the effectiveness of early implant placement with simultaneous contour augmentation through guided bone regeneration with a 2-layer composite graft in post extraction single-tooth sites over an observation period of 10 y among 20 patients		Concluded the long-term effectiveness of early implant placement with simultaneous contour augmentation through GBR with a 2-layer composite graft in post extraction single-tooth sites is predictable over an observation period of 10 yrs.

4. Larsson, L, Decker, AM, Nibali, L, Pilipchuk, SP, Berglundh, T & Giannobile, W V 2016, 'Regenerative Medicine for Periodontal and Peri-implant Diseases.', *J Dent Res*, vol. 95, no. 3, pp. 255–66.

5. Melcher, A. H. On the repair potential of periodontal tissues. *J Periodontol* 1976,47, 256-260.

6. Gottlow, J., Nyman, S., Karring, T. & Lindhe, J. New attachment formation as the result of controlled tissue regeneration. *J Clin Periodontol* 1984, 11, 494-503.

7. AAP (1992) Glossary of Periodontal Terms. *Amer Acad Periodontol*.

8. Garrett, S. Periodontal regeneration around natural teeth. *Ann Periodontol* 1, 1996,621-666.

9. S Ivanovski* Periodontal regeneration. *Aust Dent J* 2009; 54:(1 Suppl): S118–S128

10. Reynolds MA, Aichelmann-Reidy ME, Branch-Mays GL, Gunsolley JC. The efficacy of bone replacement grafts in the treatment of periodontal osseous defects. A systematic review. *Ann Periodontol* 2003;8:227–265.

11. Murphy KG, Gunsolley JC. Guided tissue regeneration for the treatment of periodontal intrabony and furcation defects. A systematic review. *Ann Periodontol* 2003;8:266–302.

12. Jepsen S, Eberhard J, Herrera D, Needleman I. A systematicreview of guided tissue regeneration for periodontal furcation defects. What is the effect of guided tissue regeneration compared with surgical debridement in the treatment of furcation defects? J *Clin Periodontol* 2002;3:103–116. discussion 160-102.

13. Richardson, C. R., Mellonig, J. T., Brunsvold, M. A., McDonnell, H. T., & Cochran, D. L. Clinical evaluation of Bio-Oss: a bovine-derived xenograft for the treatment of periodontal osseous defects in humans. *J Clin Periodontol*, 1999, 26(7), 421-428.

14. Clergeau, L. P., Danan, M., Clergeau-Guerithault, S., & Brion, M. Healing response to anorganic bone implantation in periodontal intrabony defects in dogs. Part I. Bone regeneration. A microradiographic study. *J Periodontol*, 1996, 67(2), 140-149.

15. Stavropoulos, A., Windisch, P., Szendroi-Kiss, D., Peter, R., Gera, I., & Sculean, A. Clinical and histologic evaluation of granular Beta-tricalcium phosphate for the treatment of human intrabony periodontal defects: a report on five cases. *J Periodontol,* 2010, 81(2), 325-334.

16. Rabalais ML Jr, Yukna RA, Mayer ET. Evaluation of durapatite ceramic as an alloplastic implant in periodontal osseous defects. I. Initial six-month results. *J Periodontol*. 1981 Nov;52(11):680-9.

17. Meffert, R. M., Thomas, J. R., Hamilton, K. M., & Brownstein, C. N. Hydroxylapatite as an alloplastic graft in the treatment of human periodontal osseous defects. *J Periodontol*, 1985,56(2), 63-73.

18. Yukna, R. A., Harrison, B. G., Caudill, R. F., Evans, G. H., Mayer, E. T., & Miller, S. Evaluation of durapatite ceramic as an alloplastic implant in periodontal osseous defects. II. Twelve month reentry results. *J Periodontol*, 1985, 56(9), 540-547.

19. Brown, G. D., Mealey, B. L., Nummikoski, P. V., Bifano, S. L., & Waldrop, T. C. Hydroxyapatite cement implant for regeneration of periodontal osseous defects in humans. *J Periodontol*, 1998, 69(2), 146-157.

20. Barnett, J. D., Mellonig, J. T., Gray, J. L., & Towle, H. J. Comparison of freeze-dried bone allograft and porous hydroxylapatite in human periodontal defects. *J Periodontol*, 1989, 60(5), 231-237.

21. Nery, E. B., Lee, K. K., Czajkowski, S., Dooner, J. J., Duggan, M., Ellinger, R. F.et al. A Veterans Administration Cooperative Study of biphasic calcium phosphate ceramic in periodontal osseous defects. *J Periodontol*, 1990,61(12), 737-744.

22. Jensen, S. S., Yeo, A., Dard, M., Hunziker, E., Schenk, R., & Buser, D. Evaluation of a novel biphasic calcium phosphate in standardized bone defects: a histologic and histomorphometric study in the mandibles of minipigs. *Clin Oral Implants Res*, ,2007,18(6), 752-760.

23. Ong, M. M., Eber, R. M., Korsnes, M. I., MacNeil, R. L., Glickman, G. N., Shyr, Y., & Wang, H. L. Evaluation of a bioactive glass alloplast in treating periodontal intrabony defects. *J Periodontol*, 1998 69(12), 1346-1354.

24. Kenney, E. B., Lekovic, V., Han, T., Carranza, F. A., Jr., & Dimitrijevic, B. The use of a porous hydroxylapatite implant in periodontal defects. I. Clinical results after six months. *J Periodontol*, 1985,56(2), 82-88.

25. Stahl, S. S., Froum, S. J., & Tarnow, D. Human clinical and histologic responses to the placement of HTR polymer particles in 11 intrabony lesions. *J Periodontol*,1990, 61(5), 269-274.

26. Jensen SS, Bosshardt DD, Gruber R, Buser D. Long-term stability of contour augmentation in the esthetic zone:

histologic and histomorphometric evaluation of 12 human biopsies 14 to 80 months after augmentation. *J Periodontol*. 2014 Nov;85(11):1549-56.

27. Gelb DA. Immediate implant surgery: three-year retrospective evaluation of 50 consecutive cases. *Int J Oral Maxillofac Implants*. 1993;8(4):388-99. PMID: 8270307.

28. Zitzmann NU, Schärer P, Marinello CP. Factors influencing the success of GBR. Smoking, timing of implant placement, implant location, bone quality and provisional restoration. *J Clin Periodontol*. 1999 Oct;26(10):673-82.

29. Buser D, Chen ST, Weber HP, Belser UC. Early implant placement following single-tooth extraction in the esthetic zone: biologic rationale and surgical procedures. *Int J Periodontics Restorative Dent*. 2008 Oct;28(5):441-51.

30. Chiapasco M, Casentini P. Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration. *Periodontol 2000*. 2018 Jun;77(1):213-240.

31. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clin Oral Implants Res*. 2007 Oct;18(5):552-62.

32. Bazrafshan N, Darby I. Retrospective success and survival rates of dental implants placed with simultaneous bone augmentation in partially edentulous patients. *Clin Oral Implants Res*. 2014 Jul;25(7):768-73.

33. Chappuis V, Rahman L, Buser R, Janner SFM, Belser UC, Buser D. Effectiveness of Contour Augmentation with Guided Bone Regeneration: 10-Year Results. *J Dent Res*. 2018 Mar;97(3):266-274.

34. Electronic/website sources for commercially available graft materials in Australia

- MinerOss- https://www.dentalcommunity.com.au/news/biohorizons-merges-local-operations-with-henry-schein-halas/94712019-cfa2-ee7c-21ec-57031416a597
- Puros Allograft- https://www.zimvie.com.au/en/dental/biomaterial-products/puros-ci-particulate-allograft-gl.html#overview
- Oravance- https://henryschein.com.au/oral-surgery/grafting-materials
- Milled Bone- https://australianallografts.com.au/allografts/
- Bio-Oss- https://www.geistlich.com.au/dental-professionals/bone-substitutes/geistlich-bio-oss
- Bio-Oss Collagen- https://www.geistlich.com.au/dental-professionals/bone-substitutes/bio-oss-collagen
- Endobon Xenograft- https://www.zimvie.com/en/dental/biomaterial-solutions/endobon-xenograft-particulate-gl.html
- MinerOss X,XP – https://henryschein.com.au/search?ProductSearch=graft
- https://henryschein.com.au/oral-surgery/grafting-materials/mineross-xp-cancellous-0-5cc-0-25-1mm
- MinerOss X plug- https://henryschein.com.au/search?ProductSearch=graft
- Straumann Bone ceramic, Straumann® XenoFlex and Cerabone® Granules- https://shop.straumann.com/au/en_au/Biomaterials/Bone-Subsitutes/c/cat_stmn_bonesubs
- EthOss® - https://medident.com.au/brands/ethoss/
- MIS BONDBONE™,4BONE™ BCH, BVital GenOSS Granules BS-G005 https://www.moredent.com.au/search?q=bone+graft
- NovaBone Putty- https://www.device.com.au/our-brands/NovaBone
- RTR + 80/20 – https://henryschein.com.au/search?ProductSearch=graft
- https://henryschein.com.au/oral-surgery/grafting-materials/rtr-80-20-synthetic-bone-syringe-0-5cc-granules-0-5-1mm
- RTR + 40/60- https://henryschein.com.au/search?ProductSearch=graft
- Osteon II- https://www.minimaximplant.com.au/bone-regeneration/osteon2/
- OSSIX™ Bone, OSSIX™ plus, OSSIX™ Volumax https://www.dentsplysirona.com/enau/shop/brands/ossix.html?utm_source=google&utm_medium=cpc&utm_campaign=2023_ANZ_EN_ENT_Ecomm_DT_implants_brand_productnames&utm_term=dentsply%20ossix&utm_content=138719212018&gad=1&gclid=CjwKCAjwhJukBhBPEiwAniIcNYY9nIZ6kHRuRxh8S8OzYAktUxuf19fTn34G4cxjssVxAJR8R2jluxoCW6YQAvD_BwE

Join us

Combined Conference

Gold Coast

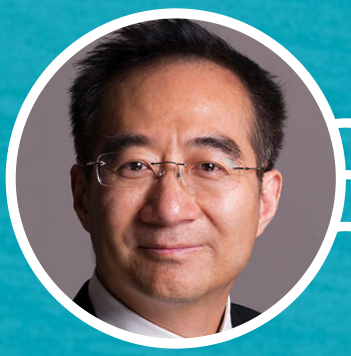
AOS · ASP · APS

Staying between the flags

19 – 21 Sep 2024

Gold Coast Convention and Exhibition Centre

Keynote speakers



Dr Joseph Kan

Prof Purnima Kumar

Dr Franck Renouard

Tabitha Acret

Mr Graham Blackbeard

Dr Kris Chmielewski

Dr Ioana Datcu

EMS · SOUTHERNIMPLANTS · straumann · ZimVie

Dr Rebecca Ellis

Dr Eugene Foo

Dr Salah Huwais

Prof Koo Ki-Tae

Dr Rodrigo Neiva

EMS · OSSTEM IMPLANT · SOUTHERNIMPLANTS · MEGAGEN OCEANIA · Dentsply Sirona

Poster competition now open, for more information visit:

Contact: Terri Lowsley, terri@conference.nz

www.aosaspaps.com

VOLUME 8 | Issue 1 | April 2024

The Australian Journal of Periodontology
and Implant Dentistry

Clinical Indications and Long-term Outcomes of SLActive and SLA Surface Implants: A Narrative Review

Dr Alan Zhu
The University of Queensland, School of Dentistry, Herston, Australia

Introduction

Dental implants have been used to replace missing teeth with predictable clinical outcomes for up to 20 years (1-3). However, placement of dental implants can result in biological and mechanical complications, which could ultimately lead to implant failure and loss (4, 5).

An important variable that can affect the implant success and survival is the implant surface characteristic. The surface property plays a significant role in the rate and degree of osseointegration around an implant, which is a key aspect of implant success and survival. Initial machine surfaced implants were found to have good survival rates but did not perform well in poor quality and compromised bone sites (1, 6). The introduction of micro-rough surface implants demonstrated an increase in the rate and degree of osseointegration, and thus improving the success and survival of implants placed in poor bone quality sites, such as the posterior maxilla (7). More recently, a newer generation of implant surfaces involving chemical modification and nanostructure formation has been developed to improve the rate of osseointegration, however, it is still not clear whether such surface modifications offer long-term clinical benefits compared to the micro-rough surface implants.

Of particular interest in this review are Sand-blasted, Large grit, Acid-etched, SLA® (Straumann, Basel, Switzerland) and SLActive® (Straumann, Basel, Switzerland) implant surfaces. The SLA implants were introduced in 1997 and are well documented with a myriad of pre-clinical and clinical studies with up to 20-year outcomes demonstrating its long-term clinical predictability (8-12). Further chemical modification of the SLA implant was explored, and a hydrophilic implant surface (SLActive) was introduced. In addition to the usual SLA surface treatment, SLActive implants are rinsed under nitrogen to prevent exposure to air and are then stored in a sealed glass tube containing isotonic sodium chloride (13). The result of the SLActive preparation method is a higher surface energy on the implant, which ultimately makes it more hydrophilic in nature. In addition, changes in nanoroughness have been reported on these surfaces,

Abstract:

Titanium dental implants are widely used to replace missing teeth and have shown predictable clinical outcomes. However, they can sometimes fail. One crucial factor influencing implant success is the implant surface characteristic, as it can play a significant role in the rate and extent of osseointegration. This review aims to provide background information on implant osseointegration, surface classification, and surface design. Additionally, it explores the current evidence on the long-term success and survival rates of hydrophilic moderately rough (SLActive®, Straumann, Basel, Switzerland) compared to hydrophobic moderately rough (SLA®, Straumann, Basel, Switzerland) surface implants.

There is limited evidence on the long-term clinical outcomes of SLActive compared to SLA surface implants. There is strong evidence showing improved early osseointegration of the SLActive surface compared to the SLA surface. However, the evidence behind the clinical use of SLActive over SLA surface implants in immediate/early loading, medically compromised patients and sinus augmented sites is weak.

In healthy patients with sufficient bone quality and quantity, both implant surfaces have the potential to shorten treatment time with respectable predictability for immediate and early loading. However, existing evidence suggests similar clinical outcomes for both surfaces, with minimal advantage in using SLActive surface implants over SLA.

For medically compromised individuals, limited conclusions can be drawn from the evidence due to the low number of experiments available and the short follow-up time. In diabetic patients, pre-clinical studies have suggested enhanced osteogenesis and

which may also contribute to the stronger bone response (14). Consequently, the modified implant surface could achieve secondary osseous stability earlier than the hydrophobic micro-rough surface, leading to a faster rate of osseointegration (15).

However, as the literature currently stands, it is unclear whether these latest chemical and nanostructure modifications offer long-term clinical benefits over the SLA surface. This gives rise to important clinical questions:

1. Why should clinicians consider using SLActive over SLA implants?
2. Is there any benefit in placing an SLActive implant compared to an SLA implant?

This narrative review aims to provide background information on implant osseointegration, implant surface classification and design. In addition, the current evidence on the long-term success and survival rates and the potential clinical indications of SLActive compared to SLA surface implants has been explored.

1. Osseointegration

Osseointegration was first described in 1969 by Brånemark *et al* (16) as "a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant". The process of osseointegration depends on the bone formed on the implant surface and the bone growth towards an implant surface, which have been described as contact and distant osteogenesis, respectively (17). Contact osteogenesis is described as the new bone forming directly on the implant surface, which is observed at one week post implant placement. At 14 days, osteogenesis takes place at a distance from the implant surface and hence is termed "distance osteogenesis". The temporal sequences of the biological events during osseointegration have been well demonstrated in pre-clinical studies (18, 19), which have revealed differences in the rate of osseointegration between different types of implant surfaces.

For osseointegration to occur following implant placement, primary and subsequent secondary stability must be established between the bone and titanium fixture surface (Figure 1). Primary stability is defined as the initial mechanical stability achieved by mechanical engagement and friction between the implant surface and the bone (20).

Abstract: ***(continued)***

bone-to-implant contact percentage (BIC%) with SLActive surfaces compared to SLA surfaces, while clinical studies have not found significant differences in implant survival rates. Osteoporotic studies have been limited to animals but have shown increased BIC% around SLActive surfaces compared to SLA surfaces. In irradiated patients, SLA surface implants may be sufficient to increase survival and success rates, and an SLActive surface may not be necessary.

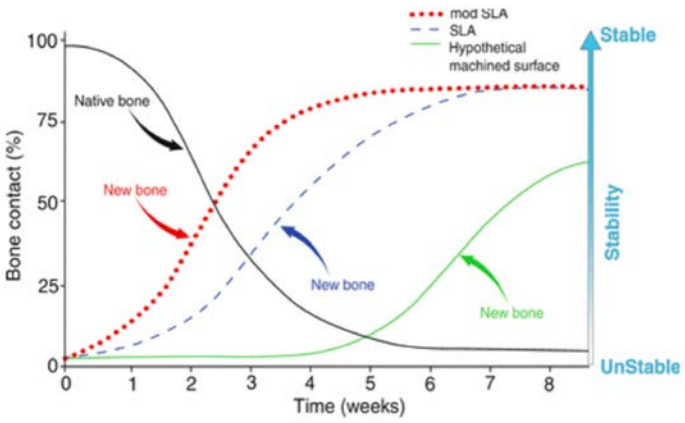
In the sinus-augmented maxilla, there is greater BIC% around SLActive surface implants during the early osseointegration stage, but the long-term clinical benefit is yet to be determined.

Consequently, the long-term clinical significance of the different implant surfaces remains unclear. While there is a biological rationale for their use in early loading, medically compromised patients, and sinus augmentation areas, there is insufficient evidence to suggest any benefit in using SLActive over SLA surface implants in the long term.

Keywords: dental implant, implant success rate, implant survival rate, implant surface characteristic, SLA, SLActive

After implant placement, the surrounding bone responsible for primary stability undergoes a resorptive process led by osteoclasts and is replaced by newly formed mineralised tissue at both the implant surface and parent bone fronts (contact osteogenesis). Meanwhile, newly formed mineralised tissue (i.e., woven bone) is gradually deposited along the parent bone and the implant surface, establishing the secondary stability (distance osteogenesis). This is ultimately exhibited as osseointegration of the dental implant to the surrounding alveolar bone and the sum of primary and secondary stability is known as the total stability (21) (Figure 1). Any disruption of the stability during the healing process such as early functional loading could introduce micromotion (22) and soft tissue infiltration into the osseous wound space, ultimately leading to osseointegration failure by encapsulation (23).

Figure 1. Implant Stability Curve Comparing Mod SLA, SLA and Machined Surface Implants



Adapted from (Roehling, Meng, & Cochran, 2015)

2. Implant surface classification

Currently, there is no consensus on how implant surfaces should be characterised or classified, but there have been suggestions by different authors. Early studies described surfaces to be "rough" or "smooth", however, this does not provide an accurate enough description of the implant surface topography. Most of the current literature uses the parameter "R_a", which describes an average roughness by measuring the deviation of a surface from a mean height. The main limitation of this measurement is that it is a two-dimensional (2D) parameter and thus cannot differentiate between the peaks and valleys, spatial position, and spatial wavelengths of the surface texture. S_a is the three-dimensional (3D) equivalent measure of R_a and can provide a more accurate description of the surface texture. It has been suggested that both R_a and S_a values should be included to characterise titanium surface topography (24).

In 2009, the consensus report from the Periodontology Workshop classified implant surfaces according to their roughness (25). The report described surface roughness using S_a values, concluding that a S_a value of 1.5 µm to be an optimum osteogenic response. However, since topographic and chemical properties can confound one another, this classification has since been deemed as insufficient and inapplicable.

Another classification approach has been proposed by categorising the commercially available dental implants into different generations based on how they have evolved over time (26). Three categories in surface modifications of commercially available implants were broadly described by the author – 1st generation (machine surfaces), 2nd generation (micro-rough surfaces) and 3rd generation (bioactive surfaces). This classification may be sufficient for clinicians, however, from a research and development point of view, an accurate scientific characterisation of the implant surface is required to directly compare experimental results. As such, an alternative classification has been proposed, which categorises dental implants by their physical characteristics (microtopography, nanotopography, global architecture) and their chemical composition (core material, chemical modifications) using a codification system (24). This system provides well-defined terminology that can be implemented by researchers to consistently compare different implant surfaces, which will allow implant companies to provide more transparent and clear definitions of their products.

For simplicity, this review categorises dental implant surfaces using different generations as suggested by Ivanovski (26).

1st generation – Machined/smooth/turned surface titanium implants

These implant surfaces represent the original dental implant surface described by Brånemark *et al* (16). Although these implant surfaces are described as "smooth", scanning electron microscopy analyses show grooves and ridges created during the manufacturing process and therefore, these implants do have a small degree of roughness.

These machined surface implants were the most used until the mid 1990s and thus, have the longest clinical documentation (1, 27). The traditional healing protocol was a healing period of 3 months in the mandible and 6 months in the maxilla in fully healed ridges (16).

2nd generation – Micro-rough surface implants

Although machined surface implants proved successful in the long-term, indications were limited to healthy subjects with sufficient bone, and the long treatment periods were a potential limitation (28). Implants with micro-rough surfaces were developed in the 1990s, based on the concept that rougher surfaces could provide more mechanical interlocking between the implant surface and bone. Two different methods have been developed and used to modify the implant surfaces and are categorised as either additive or subtractive. Briefly, additive methods attach additional material onto the implant surface usually via plasma spraying or anodization, while subtractive methods remove the implant surface layers through grit blasting and/

or etching. Different implant modifying techniques include sand blasting with large grit sand particles, acid etching, double acid etching (DAE), TiO_2 surface blasting and anodic oxidation. The degree of roughness varies between each of the different types of techniques but commonly range from 1-2 µm in roughness.

In-vivo animal studies have shown enhanced BIC% (29) and higher torque removal values (30) in 2nd generation implants when compared to machined implants. Furthermore, studies have demonstrated that micro-rough implant surfaces have greater strength than smoother titanium surfaces (11, 31), while also increasing implant success and rate of osseointegration compared to machined surfaces (32-34).

3rd generation – Bioactive surface implants

3rd generation implants attempt to enhance osseointegration even further by chemical modifications and/or incorporating nanostructures onto the existing micro-rough surface implants. Chemical modifications to the implant surface alter the implant surface chemistry by introducing molecules, ions, or crystals into the core material itself or the titanium oxide layer. *In-vivo* experiments have demonstrated that the titanium oxide layer can be modified by incorporating ions such as calcium, magnesium, phosphorous and sulphur (35, 36). Studies conducted by the same group found improved *de novo* bone formation compared to that of machined surface implants. In addition, the titanium oxide layer can be etched with hydrofluoric acid in order to introduce fluorine, which has been shown to enhance healing and osteogenesis (37, 38). Chemical modification of titanium surfaces also changes the wettability of the titanium surface, as well as the nanoroughness of these implant surfaces. As such, when comparing the 3rd generation implant surfaces with their predecessors, it has been demonstrated there is a noticeable difference in nanoroughness (14). This may indicate that the enhanced osseointegration achieved by the newer generation of implants may be due to the change in nanoroughness.

Some of the examples currently available in the market include modified SLA surface (SLActive), TiO_2 blasted surface modified by incorporation of fluoride ions and nanometre scaled discrete crystalline deposition (DCD) calcium phosphate surface.

Pre-clinical and clinical studies have consistently demonstrated early increased BIC% (15), greater removal torque values (39) and earlier mature bone formation (40) on the SLActive surface compared to the SLA surface.

3. Clinical significance of implant surface characteristics

Implant surface modification is an effective strategy for improving the rate and quality of osseointegration. Surface modifications, chemically and/or mechanically, can improve the osteoconductivity and biocompatibility of an implant surface, thereby enhancing the rate of osseointegration. It carries clinical significance by potentially allowing clinicians to restore implants earlier and providing greater predictability in clinical outcomes for implants placed in sites with compromised bone.

Implant surface modifications were introduced to induce controlled and rapid osseous healing to enhance osseointegration and reduce the magnitude and duration of the "stability dip" (41). As seen in Figure 1, early machined surface implants require a longer period for osseointegration due to its reliance on distance osteogenesis only, while SLA surface implants have a smaller "stability dip" and an increased rate of osseointegration. In addition, chemical modification of SLA surfaces has been demonstrated to further reduce the "stability dip" time which will be discussed in more detail later.

The topographic/morphological and chemical properties are two major features when characterising implant surfaces. However, as mentioned above, within the commercially available implants, there is no consensus in how they should be categorised because the methods to modify the surface topography will often change the surface chemistry and *vice versa*.

The surface topography may be divided into macro, micro and nano features. At the macro level, the features are more related to implant geometry, which is out of the scope of this review. At a micro level, the significance of micro-scale roughening of implant surfaces was first shown in 1992 by Gotfredsen *et al* (42) where they found accelerated and enhanced *de novo bone* formation around implants that had undergone titanium dioxide (TiO_2) grit blasting. Further studies demonstrated greater BIC% compared to smooth surface implants (43, 44). At a nano scale, the use of nanotechnology in relation to implant surface modification has been restricted to the creation of "nanofeatures" on the implant surface. The use of this technology was investigated since topography at the nano level may lead to increased adsorption of proteins and adhesion of cells (45), which could enhance bone formation. In a recent review article, it has been suggested

that nanoscale features on implant surfaces could also improve the process of osseointegration through the loading of biologics (e.g., bone morphogenetic protein 2), and further suggested that modification of the implant collar surface could improve the soft tissue integration between the implant and the soft tissue (46). However, the ideal nanotopography surface is yet to be realised to achieve these proposed beneficial effects.

4. SLA vs SLActive Surfaces

The SLA (hydrophobic) and SLActive (hydrophilic) implants are of particular interest in this review. The SLA implants were introduced in 1997 and have been very successful and widely used. In 2005, Straumann then introduced the SLActive implant and claimed that this implant surface could achieve secondary stability earlier by shifting the "stability dip", leading to a faster rate of osseointegration compared to the SLA implants (Figure 1).

SLA implants are sandblasted with long grit corundum (0.25-0.5mm corundum particles at 5 bar), followed by acid etching with sulphuric and hydrochloric acid and then stored dry. SLActive implants are also sandblasted, and acid etched using the same method, however subsequently, SLActive implants are rinsed under nitrogen to prevent exposure to air and are then stored in a sealed glass tube containing isotonic sodium chloride (NaCl). The result of the SLActive preparation method is a higher surface energy on the implant, which ultimately makes it more hydrophilic in nature. In addition, changes in nanoroughness have been reported on these surfaces, which may also contribute to the stronger bone response (14).

Historically, the idea of high surface energy and hydrophilic implants was initially suggested in 1984 by Baier *et al* (47), who compared different surface energy states on implant surfaces placed in the backs of rabbits. They found that higher surface energy materials produced a significantly stronger "conditioning" film that could only be broken through cohesive failure, when compared to the lower surface energy materials. However, these results were not validated in future studies possibly due to the high surface energy of the implant losing its physical properties prior to contact with biological tissues due to air contamination (48).

Consequently, the SLActive implant surface is stored in a tube containing isotonic NaCl solution to prevent exposure of the implant to air, in order to limit the adsorption of potential contaminants such as hydrocarbons and carbonates, to allow the SLActive implant to retain its high surface energy prior to implant placement (13).

The long-term success rates of SLA implants are well documented with a myriad of pre-clinical (10, 11, 29) and clinical studies with up to 20-year outcomes (8, 9, 12). In contrast, SLActive implant success rates over the long-term are limited with most studies including implants under three years in function and mainly in the context of immediate and early occlusal loading (49-51).

It is important to note that due to the similarity in surface topography between the two implant surfaces, it may be reasonably assumed that SLActive surface implants would have similar implant success rates compared to SLA surface implants in comparable situations. However, it is not yet clear whether the SLActive surface provides any additional benefit over the SLA surface.

5. Clinical performance of the SLActive Surface

Given there was promising early data around hydrophilic implant surfaces improving the rate of osseointegration, *in-vitro, in-vivo* and clinical studies have been performed to determine the clinical significance of this implant surface.

In-vitro studies

Multiple *in-vitro* studies have investigated the cellular effects of SLActive surfaces (52-54). Human osteoblast-like MG63 cells have been cultured on titanium disks with SLA and SLActive surfaces to determine differences in cell differentiation and cellular activity. The SLActive group showed increased amounts of alkaline phosphatase activity, osteocalcin and osteoprotegrin production compared to the SLA group (54). In addition, prostaglandin E2 (PGE_2) and active transforming growth factor (TGF) β1 production had increased levels on SLActive surfaces. This study suggested that the increased bone formation on SLActive surfaces could be due to the effect of the high surface energy on osteoblasts. More recently, it has been demonstrated that the SLActive implant surface promotes a higher level of osteogenic factor from mesenchymal stem cells and stimulates an M2 macrophage phenotype leading to enhanced pro-osteogenic signalling (55, 56). These results suggest that SLActive surfaces may provide a more favourable micro-environment for bone formation compared to SLA surfaces.

In-vivo studies

There are several short-term *in-vivo* studies evaluating the osseointegration of SLActive titanium implants. They consistently demonstrate early and improved osseointegration of SLActive implant surfaces when comparing with SLA. Buser *et al* (15) compared the BIC% of SLActive and SLA implants after 2, 4 and 8 weeks of healing in six miniature pigs receiving 46 implants in a split mouth design. They found that SLActive implants had significantly higher BIC% at 2 and 4 weeks compared to SLA, however, no differences at 8 weeks. Similarly, in a canine model, Bornstein *et al* (57) found higher BIC% at 2 weeks for SLActive implants, however, this difference was no longer apparent at 4 weeks. Overall, the rate of osseointegration appeared to be faster in SLActive compared to SLA implants, however, no differences were reported after 6-8 weeks of healing.

Few studies have described the quality of bone around SLActive compared to SLA surfaces (58, 59). Schwarz *et al* (58) assessed the bone formation, peri-implant tissue reaction, angiogenesis, osteocalcin activity and the BIC% in dogs. At day 14, SLActive implants showed more firmly attached, mature, parallel fibred woven bone compared to SLA. Furthermore, the loose connective tissue started to extend and attach perpendicularly to the implant surface. In addition, the biomechanical properties of SLActive surface implants appeared to have higher removal torque values and interfacial stiffness compared to SLA (39). These results demonstrated that the quality of bone around SLActive implant surfaces may be stronger compared to SLA but further studies in humans for a longer period are required.

Clinical studies

Human studies have also found similar results. In 2011, Lang *et al* (40) placed 49 SLA or SLActive implants with a diameter of 2.8mm and a length of 4mm in the mandibular retromolar area of 28 human volunteers and retrieved them after days 7, 14, 28, and 42 of healing. Thirty specimens were collected and analysed. At 7 and 14 days, there were no differences observed in terms of BIC%. At 28 days, there was a statistically significant higher BIC% for SLActive compared to SLA. At 42 days, the BIC% had increased in both groups but there were no differences between them.

A pilot study by Oates *et al* (60) placed 62 implants in 31 patients with either an SLActive or SLA surface in both the maxilla and mandible to evaluate the changes in implant stability over time. Overall, there was no significant differences between the implant surfaces after 6 weeks, but the authors did identify an earlier transition point from decreasing implant stability to increasing implant stability in the SLActive group compared to the SLA group. This may suggest a change in bone metabolism from a primarily resorptive to a primarily formative environment associated with the implant surface. However, such a difference in stability levels must be interpreted cautiously as the clinical significance is not yet clear.

The studies discussed above only have a maximum follow up period of 12 weeks, and do not indicate the long-term success rates of SLActive implants. Nevertheless, they do show promising results through earlier and faster osseointegration with SLActive compared to SLA surfaces. This has led to the idea of using SLActive implants in poorer bone quality areas, medically compromised patients and to reduce treatment time by early loading. There are multiple clinical studies beginning to investigate this gap in the research, but currently ambiguity remains as to whether there is any benefit in selecting SLActive over the well-documented SLA implants.

6. Potential clinical indications for the use of SLActive surface implants

Early and immediate loading

There are multiple dental implant placement and loading protocols that can be applied. Traditionally, implant placement and loading protocols have been analysed separately from each other (61-63), however, the implant placement technique and surgical situation can influence the selection of a certain loading protocol. Consequently, in 2018 Gallucci *et al* (64) combined the different implant placement and loading protocols into: immediate placement and immediate loading (Type 1A); immediate placement and early loading (Type 1B); immediate placement and conventional loading (Type 1C); early placement and immediate loading (Type 2-3A); early placement and early loading (Type 2-3B); early placement and conventional loading (Type 2-3C); late placement and immediate loading (Type 4A); late placement and early loading (Type 4B); late placement and conventional loading (Type 4C). Each of these options have different clinical considerations but for type 1A, 1B, 2-3A, 2-3B, a reduction in treatment time is certainly attractive for patients and clinicians, especially type 1A. Surface characteristics of implants is an area of research that has shown potential to improve and achieve earlier and faster osseointegration,

which would allow for greater predictability in early and immediate implant loading.

For clinical studies, it is important to consider the different reporting methods of studies in terms of survival and success of dental implants. It is ideal for a study to strictly define the success criteria and report success rate instead of survival. However, many studies only report the survival rate, which is a major limitation.

SLActive Implants

SLActive implants have demonstrated to be predictable in early and immediate loading in the short-term. In 2009, Bornstein *et al* (49), Bornstein *et al* (65) placed 56 SLActive implants in the posterior mandible of 39 partially edentulous patients and loaded them after 3 weeks of healing with a screwed retained crown or fixed dental prosthesis. By 6 months, all 56 implants had integrated and at 3 years, all implants demonstrated osseointegration and a success rate of 100%.

Ganeles *et al* (50) placed 383 implants in 266 healthy patients with 197 being immediately loaded and 186 early loaded after 28-34 days. The mean bone level changes were significantly higher in the immediate loading group compared to the early loading group. This discrepancy is most likely attributed to the deeper implantation depth of the immediate implants. Over 12 months, implant survival rate was claimed to be 98% in the immediate group and 97% in the early group. Surprisingly, the authors did not report the success rates but mentioned they were lower than survival rates due to patient drop-out or the visit not being performed. In a more recent two-year prospective study, SLActive implants were placed in the posterior maxilla or mandible and loaded 21 days after placement (66). Of the 89 implants, two implants failed to integrate and were removed. Their results found a 2-year success rate of 97.7%.

Taken together, these clinical studies suggest that SLActive implants placed in adequate bone quality sites and loaded early or immediately have a highly predictable survival rate in the short to medium term. It is not possible to extrapolate these results long-term as the longest follow up is 3 years. It is also important to bear in mind that these studies do not compare against SLA surface implants.

SLA Implants

SLA implants have also demonstrated evidence of predictable early and immediate loading. Kokovic *et al* (67) compared the clinical results of immediate and early loading SLA surface implants in the posterior mandible. At 5 years, the survival rate in both groups was 100% and no statistically significant differences were found between the immediate and early loaded implants in terms of the mean crestal bone loss, bleeding index and plaque index. Another clinical study compared the survival rate and alveolar bone levels of 71 SLA implants that were loaded within 1 hour or after 3 months with a 3 year follow up (68). At 1, 2 and 3 years, there were no differences with survival rates and bone levels between the two groups.

Comparing SLA and SLActive implants

A systematic review in 2015 from Chambrone *et al* (69) assessed the survival percentage, clinical and radiographic outcomes between SLA and SLActive in protocols involving immediate and early occlusal loading. Seven randomised control trials (RCTs) and twelve prospective observational studies were included in the review. No significant differences were reported in the studies regarding survival rates or clinical parameters between immediate and early loading groups. The survival rates for SLA were 95% and 97% for SLActive. However, since there were limited RCTs available for analysis for SLActive implants and with only one study that compared SLA and SLActive directly, these results should be interpreted with caution.

More recently, Sener-Yamaner *et al* (70) compared marginal bone loss around early loaded SLA and SLActive implants (107 SLA, 68 SLActive) in 55 patients with an average follow-up of 6.5 years. They found high survival rates of 98.2% for SLA and 97% for SLActive implants and no statistical differences in terms of mean marginal bone loss.

These findings suggest that in healthy patients with adequate bone quality and quantity, both SLA and SLActive surface implants have the potential to shorten treatment time with good predictability for immediate and early loading. However, the existing evidence fails to address the advantage of using SLActive surface implants over SLA. This begs to question whether the chemical modification of the SLActive implant surface provides any additional clinical long-term benefit.

Medically compromised patients

A possible advantage of having earlier and faster osseointegration are in medically compromised patients. These include but are not limited to diabetic, osteoporotic, irradiated jaws and patients who take medications that could affect bone healing. These patients may have a poorer healing capacity which can affect the initial osseointegration of the

implant and long-term peri-implant health. Dental implants are not absolute contraindications in these situations, but the risks of implant failure are higher compared to healthy subjects (71). Therefore, implant surfaces that initiate improved and stronger bone responses may increase the chance of implant success and survival.

Diabetes

Few reports have evaluated the osseointegration of different implant surface characteristics in diabetic models. In a diabetic animal model, Schlegel *et al* (72) placed six implants in 11 diabetic and 4 healthy domestic pigs to evaluate the peri-implant bone formation differences between SLA and SLActive surface implants by assessing the BIC% and bone density at 1 and 3 months. The BIC% was reduced in the diabetic group at 30 and 90 days and at 90 days, SLActive showed higher BIC% and bone density than SLA in diabetic pigs. This study demonstrated that there is a negative effect of untreated diabetes mellitus on early osseointegration but SLActive may have the potential to accelerate osseointegration. Similarly, in a more recent study, the *in-vivo* effects of SLActive and SLA surfaces on bone formation and macrophage phenotype was investigated using a type 2 diabetic rat model (73). SLA and SLActive titanium discs were placed over extra-cranial defects in four control and four type 2 diabetic rats. They found SLActive disks enhanced osteogenesis compared to SLA in type 2 diabetic rats by promoting an immunomodulatory pro-reparative environment.

In a clinical study, a RCT was performed to evaluate the potential of SLA and SLActive surfaces to enhance implant healing and osseointegration in poorly controlled diabetic patients (74). One SLA and one SLActive implant were placed into 24 patients with type 2 diabetes at the posterior mandibular site with a total of 48 implants. There were no significant differences found and 98% of implants successfully integrated and continued to restoration demonstrating that both SLActive and SLA implants were just as successful as the other.

Overall, limited conclusions can be made from these studies due to the low number of experiments available and the short follow up time. Further long-term RCTs are required to assess the impact of SLA and SLActive surface implants in patients with poor healing.

It is important to note that in clinical practice, clinicians rarely place implants in patients with uncontrolled diabetes. Based on animal studies, bone formation and resorption are compromised in states of hyperglycaemia, which can lower the likelihood of implant success (75, 76). In addition, clinical studies have shown decreased rates of osseointegration in uncontrolled diabetic patients which could lead to increased risk of implant failure in the long-term (77). On the other hand, controlled diabetics have demonstrated similar implant success rates compared to non-diabetics (78). Therefore, clinicians will predominantly wait until the diabetes is under control before invasive and expensive treatment such as dental implants.

Osteoporosis

At present, only animal studies have been performed to investigate the effects of SLActive and SLA surface implants in osteoporotic conditions. Mardas *et al* (79) placed SLA and SLActive domes in healthy, osteoporotic and bisphosphonate treated osteoporotic rabbits, to evaluate the effect of these surfaces on bone formation. Their findings suggested that SLActive surfaces may further promote bone healing and osseointegration in osteoporotic rabbits compared to SLA and the use of bisphosphonates can delay the osseointegration of the newly formed bone.

Another study using a mouse osteoporotic model evaluated the influence of hydrophilic titanium surfaces on gene expression and bone formation during osseointegration (80). They found that the hydrophilic group presented an upregulation of genes related to osteogenic differentiation and slightly higher bone volume and BIC% compared to the hydrophobic surface. These results also suggest SLActive implant surfaces can lead to improved osseointegration in osteoporotic conditions. However, it is difficult to extrapolate these results to clinical situations as domes and customised implants were used and these animals have different bone physiology to humans. Nonetheless, these results can act as a basis for future human *in-vivo* experiments.

Irradiated jaws

Patients suffering from head and neck cancers have an increased risk of dental implant failure due to treatment with radiation therapy. Radiation can lead to decreased saliva production, reduced vascular supply and cell production resulting in compromised bone healing and delayed wound healing (81). In these patients, the radiation dose and field, the time between radiation and the implant surgery, the location (maxilla or mandible) can influence the osseointegration of the dental implants. An experimental study involving minipigs found a more profound decrease in implant stability quotient

(ISQ) values in the irradiated group compared to the non-irradiated group over a 24-week period which demonstrated the negative effects of irradiation on osseointegration (82). From a clinical perspective, Chambrone *et al* (83) performed a systematic review assessing implant loss in irradiated versus non-irradiated patients. They found the mean survival rate to range from 46-98% and reported increased risk of implant failure in irradiated patients (RR: 2.74; 95% CI: 1.86-4.05) and in maxillary sites (RR: 5.96; 95% CI:2.71-13.12). It must be considered that most of the publications reported data on machined implants and thus, survival rates may potentially be higher with micro-rough surface implants. Although they concluded that implant therapy is a viable treatment option in irradiated patients, the survival rate range is rather variable. Other studies have reported similar survival rates of dental implants in these patients to range from 78-100% (84, 85).

Since radiation therapy affects bone and wound healing, SLActive implant surfaces may have the ability to increase cell production and improve the early bone healing in irradiated jaws. More recently, a clinical study with a 5-year follow-up compared SLA and SLActive dental implants with irradiated patients (86). Twenty patients were treated with 102 implants which were placed according to a split-mouth design. They reported similar survival rates at 12-month, 3-years, and 5-years of approximately 92%, 80%, and 75% respectively, for both SLA and SLActive groups. Most of the implants considered as failures were in patients who had deceased. Interestingly, these survival rates are much higher when comparing to similar radiation therapy dose literature (87). The high success in this study could be accounted by using micro-rough surface implants instead of machine surface implants which were in most previous studies. Therefore, micro-rough surface implants such as SLA may be sufficient to increase the survival and success rates in irradiated patients and a chemically modified surface such as SLActive may not be necessary.

Overall, there is limited evidence on the use of SLActive surface implants in medically compromised patients. There are promising results that the hydrophilic surface may have improved osseointegration in terms of BIC%, but they must be interpreted with caution as they are predominantly *in-vivo* animal studies. When treatment planning for implants in poor healing patients, it may be worthwhile for clinicians to consider SLActive or hydrophilic implant surfaces as it could decrease the chance of implant failure rate. However, further long-term research is required to understand the benefits of SLActive implants in medically compromised patients.

7. Maxillary sinus and bone augmentation

Implant placement in the posterior maxilla can be challenging due to poorer bone quality, pneumatisation of the maxillary sinuses and unfavourable bone resorption patterns. As such, previous clinical studies have reported lower implant success rates in the posterior maxilla compared to the mandible (1, 6) Sinus elevation and grafting procedures including transalveolar (88) and/or lateral window (89) techniques were developed to increase the residual bone volume for subsequent implant placement and demonstrated predictable clinical outcomes (90-92). Furthermore, there are a variety of different graft materials that can be used in these techniques including autogenous, substitutes (e.g., xenograft) and a combination of both, however, the graft material does not appear to affect implant survival rates (93).

In the literature, numerous systematic reviews have reported that micro-rough implant surface implant survival rates in sinus augmented sites are enhanced compared to previous machined surface implants (91, 94) The survival rate for micro-rough implants has been reported to range from 88-100%, while machined surface implant survival rates ranged from 61-100% (95). These improved outcomes are consistent with improved BIC% and stability (30, 43) and superior histological results (18). However, with the newer generation chemically modified implant surfaces, it is still not known whether they provide any additional clinical benefit compared to micro-rough implant surfaces.

Only a small number of pre-clinical studies have investigated the effect of hydrophilic implants on bone defects and sinus grafts. These studies showed that the SLActive surface implants had a significantly greater bone regeneration capacity in dehiscence bony defects (96) and circumferential defects in canines (97). Moreover, another pre-clinical study, using a sheep sinus model, investigated the effect of the SLActive surface on early bone formation in maxillary sinuses over a four-week period and reported greater BIC% in the SLActive group at both week two and week four compared to the SLA control group (98). However, Philipp *et al* (99) found no significant differences in the mean BIC% between the two implant surfaces (SLA vs SLActive) in the grafted maxillary sinus at longer observational periods of 12 and 26 weeks by using a similar sheep sinus model. This suggests that the early benefits of a faster rate of osseointegration of the SLActive surface dissipate overtime and clinical significance of using the surface in the long-term are still unknown.

The clinical evidence of SLActive implants in sinus augmented sites is limited. A 1-year clinical and radiographic study assessed a similar hydrophilic implant (ProActive, Neoss) placed with and without bone augmentation procedures (100). Forty of the 159 implants were placed in augmented maxillary sinuses. They found survival rates of 98% for both augmented and non-augmented groups with no significant statistical differences. However, it must be noted that this study only had 1-year follow up. In addition, a 5-year longitudinal study aimed to compare SLActive implants placed in synthetic biphasic calcium phosphate (BCP) or deproteinised bovine bone mineral (DBBM) (101). Their overall implant survival and success rates were 93.5% and 84.9%, respectively, which is similar to the survival and success rates of micro-rough implant surfaces.

Conclusion

To date, there is limited evidence in the literature on the long-term outcomes of SLActive compared to SLA implants. Although there is strong evidence showing improved early osseointegration of SLActive surfaces, the long-term clinical significance of these effects is unknown. While there is a biological rationale to their use in early loading, medically compromised patients and sinus augmentation areas, there is still insufficient evidence to suggest if there is any benefit in using SLActive over SLA surface implants. Thus, further understanding of the differences between SLA and SLActive implants could assist clinicians make an evidence-based decision in selecting the most suitable implant for their patients.

References

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg*. 1981;10(6):387-416.

2. Astrand P, Ahlqvist J, Gunne J, Nilson H. Implant treatment of patients with edentulous jaws: a 20-year follow-up. *Clin Implant Dent Relat Res*. 2008;10(4):207-17.

3. Donati M, Ekestubbe A, Lindhe J, Wennström JL. Implant-supported single-tooth restorations. A 12-year prospective study. *Clin Oral Implants Res*. 2016;27(10):1207-11.

4. Derks J, Håkansson J, Wennström JL, Tomasi C, Larsson M, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: early and late implant loss. *J Dent Res*. 2015;94(3 Suppl):44s-51s.

5. Heitz-Mayfield LJ, Mombelli A. The therapy of peri-implantitis: a systematic review. *Int J Oral Maxillofac Implants*. 2014;29 Suppl:325-45.

6. Buser D, Mericske-Stern R, Pierre Bernard JP, Behneke A, Behneke N, Hirt HP. Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. *Clin Oral Impl Res*. 1997;8(3):161-72.

7. Testori T, Del Fabbro M, Feldman S, Vincenzi G, Sullivan D, Rossi R, Jr. A multicenter prospective evaluation of 2-months loaded Osseotite implants placed in the posterior jaws: 3-year follow-up results. *Clin Oral Implants Res*. 2002;13(2):154-61.

8. Buser D, Janner SFM, Wittneben JG, Brägger U, Ramseier CA, Salvi GE. 10-Year Survival and Success Rates of 511 Titanium Implants with a Sandblasted and Acid-Etched Surface: A Retrospective Study in 303 Partially Edentulous Patients. *Clin Impl Dent Rel Res*. 2012;14(6):839-51.

9. Van Velzen FJJ, Ofec R, Schulten EAJM, Ten Bruggenkate CM. 10-year survival rate and the incidence of peri-implant disease of 374 titanium dental implants with a SLA surface: a prospective cohort study in 177 fully and partially edentulous patients. *Clin Oral Impl Res*. 2015;26(10):1121-8.

10. Cochran DL, Nummikoski PV, Higginbottom FL, Hermann JS, Makins SR, Buser D. Evaluation of an endosseous titanium implant with a sandblasted and acid-etched surface in the canine mandible: radiographic results. *Clin Oral Implants Res*. 1996;7(3):240-52.

11. Buser D, Nydegger T, Oxland T, Cochran DL, Schenk RK, Hirt HP. Interface shear strength of titanium implants with a sandblasted and acid-etched surface: a biomechanical study in the maxilla of miniature pigs. *J Biomed Mater Res*. 1999;45(2):75-83.

12. Roccuzzo A, Imber JC, Marruganti C, Salvi GE, Ramieri G, Roccuzzo M. Clinical outcomes of dental implants in patients with and without a history of periodontitis. A 20-year prospective study. *J Clin Periodontol*. 2022.

13. Rupp F, Scheideler L, Olshanska N, De Wild M, Wieland M, Geis-Gerstorfer J. Enhancing surface free energy and hydrophilicity through chemical modification of

microstructured titanium implant surfaces. *J Biomed Mater Res* Part A. 2006;76A(2):323-34.

14. Meirelles L, Arvidsson A, Andersson M, Kjellin P, Albrektsson T, Wennerberg A. Nano hydroxyapatite structures influence early bone formation. *J Biomed Mater Res* A. 2008;87(2):299-307.

15. Buser D, Broggini N, Wieland M, Schenk RK, Denzer AJ, Cochran DL. Enhanced Bone Apposition to a Chemically Modified SLA Titanium Surface. *J Dent Res*. 2004;83(7):529-33.

16. Brånemark PI, Adell R, Breine U, Hansson BO, Lindström J, Ohlsson A. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg*. 1969;3(2):81-100.

17. Davies JE. Mechanisms of endosseous integration. *Int J Prosthodont*. 1998;11(5):391-401.

18. Abrahamsson I, Berglundh T, Linder E, Lang NP, Lindhe J. Early bone formation adjacent to rough and turned endosseous implant surfaces. An experimental study in the dog. *Clin Oral Implants Res*. 2004;15(4):381-92.

19. Berglundh T, Abrahamsson I, Lang NP, Lindhe J. De novo alveolar bone formation adjacent to endosseous implants. *Clin Oral Implants Res*. 2003;14(3):251-62.

20. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *Int J Prosthodont*. 1998;11(5):408-20.

21. Bosshardt DD, Chappuis V, Buser D. Osseointegration of titanium, titanium alloy and zirconia dental implants: current knowledge and open questions. *Periodontol 2000*. 2017;73(1):22-40.

22. Brunski JB. Biomechanical considerations in dental implant design. *Int J Oral Implantol*. 1988;5(1):31-4.

23. Albrektsson T, Sennerby L. Direct bone anchorage of oral implants: clinical and experimental considerations of the concept of osseointegration. *Int J Prosthodont*. 1990;3(1):30-41.

24. Dohan Ehrenfest DM, Coelho PG, Kang B-S, Sul YT, Albrektsson T. Classification of osseointegrated implant surfaces: materials, chemistry and topography. *Trends in Biotechnol*. 2010;28(4):198-206.

25. Wennerberg A, Albrektsson T. Effects of titanium surface topography on bone integration: a systematic review. *Clin Oral Impl Res*. 2009;20:172-84.

26. Ivanovski S. Osseointegration--the influence of implant surface. *Ann R Australas Coll Dent Surg*. 2010;20:82-5.

27. Attard NJ, Zarb GA. Long-term treatment outcomes in edentulous patients with implant overdentures: the Toronto study. *Int J Prosthodont*. 2004;17(4):425-33.

28. Coelho PG, Jimbo R, Tovar N, Bonfante EA. Osseointegration: Hierarchical designing encompassing the macrometer, micrometer, and nanometer length scales. *Dental Materials*. 2015;31(1):37-52.

29. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *J Biomed Mat Res*. 1991;25(7):889-902.

30. Buser D, Nydegger T, Hirt HP, Cochran DL, Nolte LP. Removal torque values of titanium implants in the maxilla of miniature pigs. *Int J Oral Maxillofac Implants*. 1998;13(5):611-9.

31. Wennerberg A, Albrektsson T. Suggested guidelines for the topographic evaluation of implant surfaces. *Int J Oral Maxillofac Implants*. 2000;15(3):331-44.

32. Cochran DL, Buser D, Ten Bruggenkate CM, Weingart D, Taylor TM, Bernard JP. The use of reduced healing times on ITI implants with a sandblasted and acid-etched (SLA) surface:. *Clin Oral Impl Res*. 2002;13(2):144-53.

33. Esposito M, Murray-Curtis L, Grusovin MG, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database Syst Rev*. 2007(4):Cd003815.

34. Lambert FE, Weber HP, Susarla SM, Belser UC, Gallucci GO. Descriptive analysis of implant and prosthodontic survival rates with fixed implant-supported rehabilitations in the edentulous maxilla. *J Periodontol*. 2009;80(8):1220-30.

35. Sul YT, Johansson C, Byon E, Albrektsson T. The bone response of oxidized bioactive and non-bioactive titanium implants. *Biomaterials*. 2005;26(33):6720-30.

36. Sul YT, Johansson CB, Petronis S, Krozer A, Jeong Y, Wennerberg A. Characteristics of the surface oxides on turned and electrochemically oxidized pure titanium implants up to dielectric breakdown: the oxide thickness, micropore configurations, surface roughness, crystal structure and chemical composition. *Biomaterials*. 2002;23(2):491-501.

37. Abrahamsson I, Albouy JP, Berglundh T. Healing at fluoride-modified implants placed in wide marginal defects: an experimental study in dogs. *Clin Oral Implants Res*. 2008;19(2):153-9.

38. Lamolle SF, Monjo M, Rubert M, Haugen HJ, Lyngstadaas SP, Ellingsen JE. The effect of hydrofluoric acid treatment of titanium surface on nanostructural and chemical changes and the growth of MC3T3-E1 cells. *Biomaterials*. 2009;30(5):736-42.

39. Ferguson SJ, Broggini N, Wieland M, De Wild M, Rupp F, Geis-Gerstorfer J. Biomechanical evaluation of the interfacial strength of a chemically modified sandblasted and acid-etched titanium surface. *J Biomed Mater Res Part A*. 2006;78A(2):291-7.

40. Lang NP, Salvi GE, Huynh-Ba G, Ivanovski S, Donos N, Bosshardt DD. Early osseointegration to hydrophilic and hydrophobic implant surfaces in humans. *Clin Oral Impl Res*. 2011;22(4):349-56.

41. Puleo D. Understanding and controlling the bone–implant interface. *Biomaterials*. 1999;20(23-24):2311-21.

42. Gotfredsen K, Nimb L, Hjörting-Hansen E, Jensen JS, Holmén A. Histomorphometric and removal torque analysis for TiO2-blasted titanium implants. An experimental study on dogs. *Clin Oral Implants Res*. 1992;3(2):77-84.

43. Cochran DL, Schenk RK, Lussi A, Higginbottom FL, Buser D. Bone response to unloaded and loaded titanium implants with a sandblasted and acid-etched surface: a histometric study in the canine mandible. *J Biomed Mater Res*. 1998;40(1):1-11.

44. Wennerberg A, Albrektsson T, Johansson C, Andersson B. Experimental study of turned and grit-blasted screw-shaped implants with special emphasis on effects of blasting material and surface topography. *Biomaterials*. 1996;17(1):15-22.

45. Gulati K, Maher S, Findlay DM, Losic D. Titania nanotubes for orchestrating osteogenesis at the bone–implant interface. *Nanomedicine*. 2016;11(14):1847-64.

46. Gulati K, Chopra D, Kocak-Oztug NA, Verron E. Fit and forget: The future of dental implant therapy via nanotechnology. *Adv Drug Deliv Rev*. 2023;199:114900.

47. Baier RE, Meyer AE, Natiella JR, Natiella RR, Carter JM. Surface properties determine bioadhesive outcomes: methods and results. *J Biomed Mater Res*. 1984;18(4):337-55.

48. Carlsson LV, Alberktsson T, Berman C. Bone response to plasma-cleaned titanium implants. *Int J Oral Maxillofac Implants*. 1989;4(3):199-204.

49. Bornstein MM, Wittneben JG, Brägger U, Buser D. Early Loading at 21 Days of Non-Submerged Titanium Implants With a Chemically Modified Sandblasted and Acid-Etched Surface: 3-Year Results of a Prospective Study in the Posterior Mandible. *J Periodontol*. 2010;81(6):809-18.

50. Ganeles J, Zöllner A, Jackowski J, Ten Bruggenkate C, Beagle J, Guerra F. Immediate and early loading of Straumann implants with a chemically modified surface (SLActive) in the posterior mandible and maxilla: 1-year results from a prospective multicenter study. *Clin Oral Impl Res*. 2008;19(11):1119-28.

51. Makowiecki A, Hadzik J, Błaszczyszyn A, Gedrange T, Dominiak M. An evaluation of superhydrophilic surfaces of dental implants - a systematic review and meta-analysis. *BMC Oral Health*. 2019;19(1):79.

52. Boyan BD, Lossdörfer S, Wang L, Zhao G, Lohmann CH, Cochran DL. Osteoblasts generate an osteogenic microenvironment when grown on surfaces with rough microtopographies. *Eur Cell Mater*. 2003;6:22-7.

53. Zhao G, Raines AL, Wieland M, Schwartz Z, Boyan BD. Requirement for both micron- and submicron scale structure for synergistic responses of osteoblasts to substrate surface energy and topography. *Biomaterials*. 2007;28(18):2821-9.

54. Zhao G, Schwartz Z, Wieland M, Rupp F, Geis-Gerstorfer J, Cochran DL. High surface energy enhances cell response to titanium substrate microstructure. *J Biomed Mater Res Part A*. 2005;74A(1):49-58.

55. Hamlet SM, Lee RSB, Moon HJ, Alfarsi MA, Ivanovski S. Hydrophilic titanium surface-induced macrophage modulation promotes pro-osteogenic signalling. *Clin Oral Impl Res*. 2019;30(11):1085-96.

56. Hotchkiss KM, Sowers KT, Olivares-Navarrete R. Novel in vitro comparative model of osteogenic and inflammatory cell response to dental implants. *Dent Mater*. 2019;35(1):176-84.

57. Bornstein MM, Valderrama P, Jones AA, Wilson TG, Seibl R, Cochran DL. Bone apposition around two different sandblasted and acid-etched titanium

implant surfaces: a histomorphometric study in canine mandibles. *Clin Oral Impl Res*. 2008;19(3):233-41.

58. Schwarz F, Ferrari D, Herten M, Mihatovic I, Wieland M, Sager M. Effects of surface hydrophilicity and microtopography on early stages of soft and hard tissue integration at non-submerged titanium implants: an immunohistochemical study in dogs. *J Periodontol*. 2007;78(11):2171-84.

59. Schwarz F, Herten M, Sager M, Wieland M, Dard M, Becker J. Histological and immunohistochemical analysis of initial and early subepithelial connective tissue attachment at chemically modified and conventional SLA®titanium implants. A pilot study in dogs. *Clin Oral Investig*. 2007;11(3):245-55.

60. Oates TW, Valderrama P, Bischof M, Nedir R, Jones A, Simpson J. Enhanced implant stability with a chemically modified SLA surface: a randomized pilot study. *Int J Oral Maxillofac Implants*. 2007;22(5):755-60.

61. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. *Int J Oral Maxillofac Implants*. 2009;24.

62. Chen ST, Wilson TG, Jr., Hämmerle CH. Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. *Int J Oral Maxillofac Implants*. 2004;19 Suppl:12-25.

63. Gallucci GO, Benic GI, Eckert SE, Papaspyridakos P, Schimmel M, Schrott A. Consensus statements and clinical recommendations for implant loading protocols. The *Int J Oral Maxillofac Implants*. 2014(29):287-90.

64. Gallucci GO, Hamilton A, Zhou W, Buser D, Chen S. Implant placement and loading protocols in partially edentulous patients: A systematic review. *Clin Oral Impl Res*. 2018;29(S16):106-34.

65. Bornstein MM, Hart CN, Halbritter SA, Morton D, Buser D. Early Loading of Nonsubmerged Titanium Implants with a Chemically Modified Sand-Blasted and Acid-Etched Surface: 6-Month Results of a Prospective Case Series Study in the Posterior Mandible Focusing on Peri-Implant Crestal Bone Changes and Implant Stabili. *Clin Impl Dent Rel Res*. 2009;11(4):338-47.

66. Morton D, Bornstein MM, Wittneben JG, Martin WC, Ruskin JD, Hart CN. Early Loading after 21 Days of Healing of Nonsubmerged Titanium Implants with a Chemically Modified Sandblasted and Acid-Etched Surface: Two-Year Results of a Prospective Two-Center Study. *Clin Impl Dent Rel Res*. 2010;12(1):9-17.

67. Kokovic V, Jung R, Feloutzis A, Todorovic VS, Jurisic M, Hämmerle CHF. Immediate vs. early loading of SLA implants in the posterior mandible: 5-year results of randomized controlled clinical trial. *Clin Oral Impl Res*. 2014;25(2):e114-e9.

68. Cesaretti G, Botticelli D, Renzi A, Rossi M, Rossi R, Lang NP. Radiographic evaluation of immediately loaded implants supporting 2-3 units fixed bridges in the posterior maxilla: a 3-year follow-up prospective randomized controlled multicenter clinical study. *Clin Oral Impl Res*. 2016;27(4):399-405.

69. Chambrone L, Shibli JA, Mercúrio CE, Cardoso B, Preshaw PM. Efficacy of standard (SLA) and modified sandblasted and acid-etched (SLActive) dental implants in promoting immediate and/or early occlusal loading protocols: a systematic review of prospective studies. *Clin Oral Impl Res*. 2015;26(4):359-70.

70. Sener-Yamaner ID, Yamaner G, Sertgoz A, Canakci CF, Ozcan M. Marginal Bone Loss Around Early-Loaded SLA and SLActive Implants: Radiological Follow-Up Evaluation Up to 6.5 Years. *Implant Dent*. 2017;26(4):592-9.

71. Gomez-De Diego R, Mang-De La Rosa M, Romero-Perez M, Cutando-Soriano A, Lopez-Valverde-Centeno A. Indications and contraindications of dental implants in medically compromised patients: Update. *Medicina Oral Patología Oral y Cirugia Bucal*. 2014:e483-e9.

72. Schlegel KA, Prechtl C, Möst T, Seidl C, Lutz R, Von Wilmowsky C. Osseointegration of SLActive implants in diabetic pigs. *Clin Oral Impl Res*. 2013;24(2):128-34.

73. Lee RSB, Hamlet SM, Moon HJ, Ivanovski S. Re-establishment of macrophage homeostasis by titanium surface modification in type II diabetes promotes osseous healing. *Biomaterials*. 2021;267:120464.

74. Khandelwal N, Oates TW, Vargas A, Alexander PP, Schoolfield JD, Alex Mcmahan C. Conventional SLA and chemically modified SLA implants in patients with poorly controlled type 2 Diabetes mellitus - a randomized controlled trial. *Clin Oral Impl Res*. 2013;24(1):13-9.

75. Gerritsen M, Lutterman JA, Jansen JA. Wound healing around bone-anchored percutaneous devices in experimental diabetes mellitus. *J Biomed Mater Res*. 2000;53(6):702-9.

76. McCracken M, Lemons JE, Rahemtulla F, Prince CW, Feldman D. Bone response to titanium alloy implants placed in diabetic rats. *Int J Oral Maxillofac Implants*. 2000;15(3):345-54.

77. Oates TW, Dowell S, Robinson M, McMahan CA. Glycemic control and implant stabilization in type 2 diabetes mellitus. *J Dent Res*. 2009;88(4):367-71.

78. Tawil G, Younan R, Azar P, Sleilati G. Conventional and advanced implant treatment in the type II diabetic patient: surgical protocol and long-term clinical results. *Int J Oral Maxillofac Implants*. 2008;23(4):744-52.

79. Mardas N, Schwarz F, Petrie A, Hakimi AR, Donos N. The effect of SLActive surface in guided bone formation in osteoporotic-like conditions. *Clin Oral Impl Res*. 2011;22(4):406-15.

80. Siqueira R, Ferreira JA, Rizzante FAP, Moura GF, Mendonça DBS, De Magalhães D, et al. Hydrophilic titanium surface modulates early stages of osseointegration in osteoporosis. *J Periodontal Res*. 2021;56(2):351-62.

81. Meraw SJ, Reeve CM. Dental considerations and treatment of the oncology patient receiving radiation therapy. *J Am Dent Assoc*. 1998;129(2):201-5.

82. Verdonck HWD, Meijer GJ, Laurin T, Nieman FH, Stoll C, Riediger D. Implant stability during osseointegration in irradiated and non-irradiated minipig alveolar bone: an experimental study. *Clin Oral Impl Res*. 2008;19(2):201-6.

83. Chambrone L, Mandia J, Jr., Shibli JA, Romito GA, Abrahao M. Dental implants installed in irradiated jaws: a systematic review. *J Dent Res*. 2013;92(12 Suppl):119s-30s.

84. Buddula A, Assad DA, Salinas TJ, Garces YI, Volz JE, Weaver AL. Survival of turned and roughened dental implants in irradiated head and neck cancer patients: a retrospective analysis. *J Prosthet Dent*. 2011;106(5):290-6.

85. Nelson K, Heberer S, Glatzer C. Survival analysis and clinical evaluation of implant-retained prostheses in oral cancer resection patients over a mean follow-up period of 10 years. *J Prosthet Dent*. 2007;98(5):405-10.

86. Nack C, Raguse JD, Stricker A, Nelson K, Nahles S. Rehabilitation of irradiated patients with chemically modified and conventional SLA implants: five-year follow-up. *J Oral Rehabil*. 2015;42(1):57-64.

87. Ihde S, Kopp S, Gundlach K, Konstantinović VS. Effects of radiation therapy on craniofacial and dental implants: a review of the literature. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2009;107(1):56-65.

88. Summers RB. The osteotome technique: Part 3-Less invasive methods of elevating the sinus floor. *Compendium*. 1994;15(6):698, 700, 2-4 passim; quiz 10.

89. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *J Oral Surg*. 1980;38(8):613-6.

90. Antonoglou GN, Stavropoulos A, Samara MD, Ioannidis A, Benic GI, Papageorgiou SN. Clinical performance of dental implants following sinus floor augmentation: A systematic review and meta-analysis of clinical trials with at least 3 years of follow-up. *Int J Oral Maxillofac Implants*. 2018;33(3):e45-e65.

91. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *J Clin Periodontol*. 2008;35:216-40.

92. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation Part II: Transalveolar technique. *J Clin Periodontol*. 2008;35:241-54.

93. Raghoebar GM, Onclin P, Boven GC, Vissink A, Meijer HJA. Long-term effectiveness of maxillary sinus floor augmentation: A systematic review and meta-analysis. *J Clin Periodontol*. 2019;46:307-18.

94. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in *Implant Dentistry*. *Int J Oral Maxillofac Implants*. 2009;24 Suppl:237-59.

95. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. *Int J Oral Maxillofac Implants*. 2009;24 Suppl:218-36.

96. Schwarz F, Herten M, Sager M, Wieland M, Dard M, Becker J. Bone regeneration in dehiscence-type defects at chemically modified (SLActive) and conventional SLA titanium implants: a pilot study in dogs. *J Clin Periodontol*. 2007;34(1):78-86.

97. Lai HC, Zhuang LF, Zhang ZY, Wieland M, Liu X. Bone apposition around two different sandblasted, large-grit and acid-etched implant surfaces at sites with coronal circumferential defects: an experimental study in dogs. *Clin Oral Impl Res*. 2009;20(3):247-53.

98. Alayan J, Vaquette C, Saifzadeh S, Hutmacher D, Ivanovski S. Comparison of early osseointegration of SLA® and SLActive® implants in maxillary sinus augmentation: a pilot study. *Clin Oral Impl Res*. 2017;28(11):1325-33.

99. Philipp A, Duncan W, Roos M, Hämmerle CH, Attin T, Schmidlin PR. Comparison of SLA®or SLActive®implants placed in the maxillary sinus with or without synthetic bone graft materials - an animal study in sheep. *Clin Oral Impl Res*. 2014;25(10):1142-8.

100. Zumstein T, Sennerby L. A 1-Year Clinical and Radiographic Study on Hydrophilic Dental Implants Placed with and without Bone Augmentation Procedures. *Clin Impl Dent Rel Res*. 2016;18(3):498-506.

101. Mordenfeld A, Lindgren C, Hallman M. Sinus Floor Augmentation Using Straumann® BoneCeramic™ and Bio-Oss® in a Split Mouth Design and Later Placement of Implants: A 5-Year Report from a Longitudinal Study. *Clin Impl Dent Rel Res*. 2016;18(5):926-36.

straumann

Straumann® | Founded on SCIENCE

EVIDENCE. INNOVATION. TRUST.

Explore Straumann® Science. Evidence-based treatment enables clinicians to make informed decisions. Find out from experts how scientific evidence plays an important role in daily clinical decisions.

DID YOU KNOW THAT OUR IMMUNE SYSTEM FAVORS ROXOLID®?

DR STEPHEN CHEN

Watch the lecture of Dr Stephen Chen to discover why

Straumann Pty Ltd/Straumann New Zealand Limited
93 Cook Street, Port Melbourne VIC 3207, Australia
AU Toll Free 1800 660 330 **NZ Toll Free** 0800 408 370
Email marketing.au@straumann.com
www.straumann.com.au | www.straumann.co.nz

VOLUME 8 | Issue 1 | April 2024

The Australian Journal of Periodontology
and Implant Dentistry

NTX-I and TRAP5b as Bone Destruction Biomarkers in Individuals with Peri-Implantitis: A Review of the Literature

Faisa Azzahra, Monisha Morshed, Tina Kamarudin
The University of Western Australia, 17 Monash Avenue, Nedlands WA 6009

Introduction

Osseointegrated implants are widely performed and are considered the gold standard for the replacement of absent teeth. (1) Despite the high success rate of 97% to 99%, increased use of implants in recent years has led to a rising occurrence of implant-related complications, with the most common ones being inflammatory and biofilm-induced, and thus biological in nature.(1) 'Peri-implant mucositis' is a plaque-induced, reversible, inflammatory condition of the gingival soft tissues characterized by bleeding on probing and visual signs of inflammation. (2) Likewise, "peri-implantitis' is also a plaque-induced inflammatory condition occurring in tissues around dental implants, characterized by clinical signs of inflammation, increased probing depths compared to baseline measurements as well as progressive loss of supporting bone.(3) It is presumed to be preceded by peri-mucositis. The prevalence of these peri-implant diseases are 47% and 20%, respectively. (4) Peri-implantitis is thought to be preceded by peri-implant mucositis, however, the features and conditions of the conversion from peri-implant mucositis to peri-implantitis have not been determined. Both conditions present an inflammatory lesion in the peri-implant mucosa, but the defining boundary is the progressive bone loss in peri-implantitis.

The diagnosis of peri-implantitis currently relies on clinical and radiological parameters, including increased probing depths (PD), bleeding on probing (BOP), and radiographic evidence of bone loss.(3) However, these current methods of assessing bone loss are limited as they are retrospective, only ascertaining the history of bone destruction and not current bone-destruction activity.(3)(5) Also, PD measurements can be inconsistent around implants due to the difficulty in probing around the contours of restorations which often do not allow for accurate probing. (3) Since bone loss is the hallmark feature of peri-implantitis, the detection of specific bone-loss biomarkers in saliva and peri-implant crevicular fluid (PICF) could play an important role in early diagnosis of peri-implantitis. PICF is an inflammatory exudate which originates from the vessels of the gingival plexus, containing host-derived enzymes, inflammatory cytokines and tissue breakdown products. (6) Early diagnosis can be achieved

Abstract:

Background: Bone modelling biomarkers such as RANKL and OPG are well established in the process of bone resorption, however, have failed to differentiate between peri-implant mucositis and peri-implantitis. This paper aims to review the literature surrounding other bone resorption biomarkers, NTX-I and TRAP5b, and their roles in bone destruction in individuals with peri-implantitis compared to peri-implant health. Their relevance in periodontitis and other non-oral metabolic bone diseases is also discussed, demonstrating their efficacy in various bone-related pathologies.

Method: a search was conducted on PubMed and Ovid, and 18 publications met the inclusion criteria for this review.

Conclusion: Both NTX-I and TRAP5b demonstrate value in the diagnosis, prognosis, and clinical performance of bone loss related pathologies. NTX-I has shown to be a promising clinical indicator to improve the diagnosis of peri-implantitis, however, there have been no studies investigating the role of TRAP5b in peri-implantitis.

by providing a better indication of pathogenic processes with increased sensitivity compared to traditional clinical parameters. It can also aid in earlier intervention and prevention of more advanced treatment approaches and prevention of more disruptive pathological processes. (3)

Bone turnover biomarkers RANKL and OPG have been investigated previously in the effort to detect bone resorption in peri-implant conditions, however, they were unsuccessful in discriminating between mucositis and peri-implantitis. (7-9) Also, RANKL and OPG are regulators of osteoclastogenesis (10), whereas bone destruction markers such as NTX and TRAP5b reflect true bone matrix destruction and would therefore be more appropriate as early peri-implantitis indicators. (11-13).

Furthermore, inflammatory cytokines have been assessed by several studies, but they may not be the ideal biomarker to differentiate between peri-implantitis and peri-implant mucositis since both peri-implant diseases involve inflammatory processes. (14) Similar to NTX, C-terminal telopeptide of type I collagen (CTX) is also a fragment of type I collagen from the telopeptide region, with CTX being the specific product of cathepsin K-mediated bone resorption, as direct digestion of bone with cathepsin K causes CTX release. (15) C-terminal cross-linked telopeptide of type I collagen (ICTP) is released by matrix metalloproteinase and has been suggested to respond more to pathways of bone resorption activated by skeletal metastases of solid tumours than those activated in postmenopausal osteoporosis.(15) CTX and NTX assays demonstrate generally similar clinical utility and test characteristics however NTX is considered a more stable fragment when compared to CTX, as CTX undergoes isomerization and racemization over time.(15) The dental literature regarding CTX has shown its use in predominantly predicting fractures in osteoporosis. (15) A recent systematic review cites NTX as a potential marker of bone destruction in peri-implantitis. (16) However, there are limited studies assessing NTX-I and TRAP5b in peri-implantitis, therefore we will review the literature surrounding NTX-I and TRAP5b in non-oral metabolic bone diseases, periodontitis and their relevance in peri-implantitis. The aim of this literature review is to assess the usefulness of NTX-I and TRAP5b in detecting bone loss in individuals with peri-implantitis.

Materials and Methods

A literature search was conducted on the following databases: PubMed and Ovid. Key words were also searched on Google Scholar. No restrictions were placed on time period and all articles were searched for relevant terms by article title, abstract and complete article. The search terms used included (peri-implantitis OR dental implant OR peri-implant mucositis OR periodontitis) AND (NTX OR TRAP5b OR biomarker*) AND (bone destruction OR bone resorption OR bone loss OR bone degradation OR implant instability). The present review included both human and animal studies, not limited to the English language. After screening of the titles and abstracts, the full text of publications was obtained for the selected articles. Key words such as 'peri-implantitis', 'NTX OR n-telopeptide OR amino-terminal', 'TRAP5b OR TRACP5b OR tartrate-resistant', 'dental implant' were also used in the search and relevant studies included. Other sources were identified using hand searches of journals and reference lists of individual articles. A further sub-classification of the studies was based on the association of NTX-I or TRAP5b with other oral or non-oral bone loss conditions. Papers were selected if they reported assessing the role of NTX-I or TRAP5b as biomarkers for bone destruction. Studies which reported the use of the aforementioned biomarkers but did not signify their relevance or value in the disease condition being studied, were excluded.

Results

A broad search of the selected databases found 18 publications that met the inclusion criteria. The most prevalent study design was cross-sectional (n = 13). A great variability in the type of bone destructive disease utilizing NTX-I and TRAP5b as diagnostic tools was observed. However, those concentrated at peri-implant diseases were limited. Thus, studies were categorized according to the disease condition being assessed: 1) non-oral metabolic bone diseases; 2) periodontitis and other oral conditions (excluding peri-implant diseases); and 3) peri-implant diseases. Of the studies which addressed peri-implant diseases, it was found that PICF samples were commonly assessed, whereas studies using saliva samples were not encountered. Despite being published in a non-indexed journal, a study by Alotaibi and colleagues (2020) has been included due to its relevant findings. (17) Additionally, two studies by Hall and colleagues assessed TRAP and not specifically the 5b isoform. (18-19) However, due to their relevant findings in peri-implantitis, the papers have been included in this review.

Discussion

Bone turnover is dynamic and involves two concomitant processes: bone deposition by osteoblasts and bone resorption by osteoclasts. The key functions of bone turnover

include renewal of old bone and maintenance of calcium homeostasis. When osteoclast activity exceeds osteoblast activity, progressive bone loss occurs. (20-21) Destruction of bone matrix results in the release of its components and enzymes reflecting the metabolic activity of osteoclasts into the circulation. N-terminal cross-linking telopeptide of type 1 collagen (NTX-I) is a product that is created by the osteoclastic cleavage and degradation of type 1 collagen, the most abundant protein of bone. Telopeptide fragments are liberated at a rate proportional to bone resorption activity. (15) Tartrate-resistant acid phosphatase 5b (TRAP5b) is a non-collagen enzyme that originates from osteoclasts, and its serum levels significantly correlate with bone resorption. (11-12) It is generally considered that TRAP5b indicates only the number, not necessarily the activity of osteoclasts. (15, 21) However, Pascual et al in 2019 determined that it does indeed reflect osteoclastic activity. (22)

NTX-I and TRAP5b in non-oral conditions

NTX-I is frequently analysed in urine or serum as a diagnostic marker or to monitor anti-resorptive therapy in individuals with bone metabolism disorders such as osteoporosis, bone metastases of cancer, and Paget's disease. (15, 20) Although bone turnover markers (BTM), including NTX-I, are not currently recommended to diagnose osteoporosis or to predict accelerated bone loss, they are useful for assessing anti-resorptive therapy in osteoporosis. (21-22) In patients with bone metastases of cancer, increased levels of NTX predicted increased rates of skeletal-related events such as fracture and disease progression, so BTMs can provide valuable prognostic utility in such patients. (23-25)

Changes in TRAP5b levels have been shown to precede radiographic changes. (26) Results from a study by Shidara et al in 2008 showed that in hemodialysis patients with renal osteodystrophy, the highest serum TRAP5b levels showed the fastest rate of cortical bone loss. (27) Due to the low sensitivity in this study, and the smaller response of TRAP5b to antiresorptive therapy compared to other bone resorption markers, (28) TRAP5b may not be suitable to assess in individual patients but may be advantageous to use in larger cohorts in research applications. Both TRAP5b and NTX-I are relevant markers for the estimation of bone resorption in a range of bone metabolism disorders. However, there are many physiologic factors and systemic conditions that influence bone marker levels and can act as potential confounders for interpretation. (15)

Generally, bone turnover marker levels in serum and urine as measured in the aforementioned conditions indicate the metabolic status of the overall skeleton, where the rate of bone turnover varies at different skeletal sites. (21) The gold standard technique of validating bone turnover markers is by histomorphometry which allows direct visual assessment of bone resorption of a particular site, however, the process in acquiring a bone biopsy is an invasive procedure. (21) In studies assessing bone loss in peri-implantitis, bone resorption markers are validated against the current clinical parameters used to diagnose the condition (PD, BOP, radiography). (3) It is anticipated that measuring NTX-I and TRAP5b levels in oral fluids from localised peri-implant sites will provide a more accurate picture of localised bone destruction compared to serum/urine analyses that measure the bone turnover process of the whole skeleton.

NTX-I and TRAP5b in periodontitis

Periodontitis is a chronic multifactorial inflammatory disease that is characterized by pathological resorption of the tooth-supporting apparatus, namely the alveolar bone. (13, 24, 29) In periodontitis, NTX is a marker of interest as it is released as an end-product of bone resorption, excluding any involvement of soft tissues around the teeth. (30-31) Type I collagen fragments have been studied in subjects with periodontitis by examining various types of fluid samples, including saliva and gingival crevicular fluids (GCF), whereas there have been limited studies on TRAP5b.

Wilson et al. measured various bone turnover markers using different sample types, including GCF, bone washes and serum. NTX was detected in all sample types, suggesting that it may be an important marker of active bone loss in periodontitis, as well as site-specific responses to periodontal treatment. However, a limitation of this study includes the possible over-dilution of samples, preventing certain markers from being detected compared to previous studies. (32) The study by Aruna in 2015 estimated the levels of NTX in GCF and correlated them with clinical parameters of periodontitis. NTX was detected in groups III (periodontitis) and IV (periodontitis receiving nonsurgical treatment), with the former reporting higher levels, and both groups correlating with the clinical parameters. Its absence in groups I (healthy) and II (gingivitis), as well as its reduction of levels from group III to IV, demonstrate its possible role as a marker of bone resorption in periodontitis. (33) In the following year, Aruna completed a separate study analysing NTX levels in plasma, with the same methodology. Results showed highest levels in Group III, and lowest in group IV, and surprisingly, middle levels in groups I and II. This suggests that plasma NTX levels may differ between subjects who are healthy, diseased and

who receive therapy, and do not accurately correlate with levels of active bone resorption. (31)

Gursoy et al. was the first study to examine the markers of periodontitis in saliva, between subjects with and without periodontitis. NTX was found at very low levels, mostly just under the detection limit, suggesting that saliva may not be a suitable sample for detecting NTX. (34) This may also be attributed to the contribution of anaerobic, periodontitis-associated bacteria such as *porphyromonas gingivalis, treponema denticola* and *prevotella intermedia* in the degradation of collagen-containing tissues of the oral cavity. (35) Surprisingly, TRAP5b levels correlated with cross-linked carboxyterminal telopeptide of type I collagen (ICTP), which is not related to osteoclastic degradation, but may be related by an alternative bone degradation pathway. (34) Becerik et al investigated GCF levels of various markers and demonstrated that NTX levels were similar across diseased and healthy groups, but Generalised Aggressive periodontitis had lower levels than Chronic Periodontitis, which may be explained by the greater diversity of bone-specific markers in the former. The presence of detectable NTX in gingivitis and healthy groups may be attributed to normal bone homeostasis. (36) Finally, the systematic review by Almehmadi and Alghamdi reviewed 23 articles detecting various biomarkers in GCF

Table 1: Studies evaluating the use of NTX-I or TRAP5b in periodontitis

Author	Year	Title	Type of study	Type of patients	Sample size	Sample type	Primary outcome
Wilson AN, Schmid MJ, Marx DB, Reinhardt RA	2003	Bone turnover markers in serum and periodontal microenvironments	Cross-sectional	Patients with untreated generalised moderate-severe periodontitis, GCF from sites >5mm PD	n =14	Bone wash	NTX can be detected in GCF samples and may be a useful diagnostic marker of periodontal bone resorption.
Aruna G	2015	Estimation of N-terminal telopeptides of type I collagen in periodontal health, disease and after nonsurgical periodontal therapy in gingival crevicular fluid: a clinico-biochemical study	Cross-sectional	Patients attending the outpatient Department of Periodontology with clinically healthy periodontium, gingivitis or periodontitis.	n = 30	GCF	Detection of NTX in periodontitis patients could be related to a greater amount of bone resorption at the diseased sites or the large pocket volume
Gursoy UK, Kononen E, Huumonen S, et al.	2013	Salivary type I collagen degradation end-products and related matrix metalloproteinases in periodontitis	Cross-sectional	Patients selected on the basis of their periodontal status: generalized periodontitis, localized periodontitis, control. All subjects had at least 20 teeth.	n = 230	Saliva	NTX was found at very low levels in saliva even in cases of generalized periodontitis. May be due to its higher thermal denaturation rate or its contribution of microbial collagenases in the further degradation of cross-linked telopeptides in saliva.
Aruna G	2016	Plasma levels of n-telopeptides of Type I collagen in periodontal health, disease after treatment	Cross-sectional	Patients categorized into three groups: clinically healthy periodontium, gingivitis or periodontitis	n = 30	Plasma	NTX concentration was highest in the periodontitis group and lowest at post-debridement. This difference was statistically significant.
Becerik S, Afacan B, Ozturk VO et al.	2011	Gingival crevicular fluid calprotectin, osteocalcin and cross-linked N-terminal telopeptide levels in health and different periodontal diseases.	Cross-sectional	Patients with chronic periodontitis, generalized aggressive periodontitis, gingivitis and healthy subjects.	n = 80	GCF	Fluctuating GCF levels of NTX might point out the abnormal bone turnover in periodontitis.

in periodontal diseases. It was concluded that NTX is an acceptable and reliable marker for subtle changes in bone turnover, however, there is not a single biomarker that has superior predictive quality over others. The general recommendation is to carry out a comprehensive clinical evaluation combined with an evaluation of biomarkers as a multi-faceted approach to achieve diagnostic and prognostic outcomes. (37)

NTX-I and TRAP5b in peri-implant diseases

While peri-implantitis and periodontitis share clinical characteristics, they represent discrete conditions. The aetiopathogenesis of peri-implantitis is similar to that of periodontitis, with both involving alveolar bone loss in addition to inflammation of the soft tissues. However, the progression of peri-implantitis is reported to be faster and more aggressive. Moreover, peri-implant lesions demonstrate a poorer blood circulation, inadequate fibrous encapsulation of inflammatory infiltrates, and distinct cell and bacteria profiles. (38-39) A limited number of studies has been conducted evaluating the use of NTX-I or TRAP5b as biomarkers to diagnose peri-implantitis.

Several small-scale or pilot cross-sectional studies have assessed NTX-I levels in peri-implant crevicular fluid (PICF) from implant sites with or without peri-implant diseases and evaluated the usefulness of NTX-I as a diagnostic marker for peri-implant diseases. Sakamoto et al. collected PICF samples from peri-implant diseased and non-diseased sites which were correlated with clinical parameters recorded for each patient, namely: PD, BOP and gingival index (GI). (40) PICF samples obtained from diseased sites contained greater levels of NTX than samples from healthy sites. These NTX levels correlated with both the bone loss rate and PD, showing high sensitivity and specificity for predicting peri-implantitis. A similar study was conducted two years later in Saudi Arabia by Alotaibi and colleagues looking at the levels of NTX in PICF. (17) The two studies showed very similar findings and conclusions. However, greater sample sizes are needed in future studies to support the results obtained herein. Typically, peri-implant bone loss levels are assessed by implant thread on radiograph. (41) Unfortunately, there are difficulties in attaining high accuracy in these methods especially when implant species differ. Consequently, this affects its sensitivity in predicting signs of early healing complications. (41) NTX levels in PICF were found to correspond with rates of bone loss therefore suggesting that bone destruction biomarkers are potentially more accurate than clinical bone loss indicators. (17, 31) Interestingly, an increase in NTX levels in PICF of dental implant patients have also shown to parallel an increase in PICF volume, when not distinguishing between healthy or diseased sites. The reasons for this remain unclear except it may indicate an upregulation in the overall bone turnover rate which may help to further predict advanced bone loss sooner than other parameters. (42) A more recent study performed by Swarup and colleagues found that NTX levels were significantly higher within the sites suffering from peri-implantitis, when compared to healthy locations and there is a positive correlation of the NTX levels with the mean values of the clinical periodontal parameters. (43)

In studies exploring markers of bone loss, TRAP was commonly expressed during osseointegration of biomaterials, and was found to be the most specific and sensitive biomarker. (44) Generally, bone healing associated with implantation of biomaterials would progress through three stages: early bone cell reactions, bone matrix deposition and bone mineralization. (45) The resorption of damaged bone by osteoclasts (which produces TRAP) is noted as a fundamental initiator for bone formation. (46) In two controlled clinical exploratory studies, (18-19) the expression of TRAP was not significantly different between healthy, mucositis and peri-implantitis subject groups. Additionally, there was an absence of bone resorption markers even in subjects exhibiting strong clinical signs of peri-implantitis, which indicates that it was not possible to establish ongoing bone degradation in these subjects. Reasons for these findings could either be that bone loss in the peri-implantitis group had likely occurred before the time point for PICF sampling or that the presence of bone resorption markers was below the limit of detection for the qPCR assay. Therefore, sampling and qPCR analysis of PICF may not be a productive method for the assessment of ongoing bone resorption. Contrarily, in Albeshri and colleagues' systematic review assessing biomarkers as independent predictors of bone regeneration around biomaterials, animal studies demonstrated that TRAP was correlated with the early stage of cellular response to biomaterials and significantly corresponded to osteoclast-like activity. Whereas, the presence of TRAP5b was observed early in the postoperative immunoassays thus demonstrating a difference between TRAP and TRAP5b. (44, 47-50) However, due to this distinction between TRAP and its 5b isoform, future studies will need to be specifically evaluate TRAP5b's ability in reflecting bone loss.

Table 2: Studies evaluating the use of NTX-I or TRAP5b in peri-implant conditions

Author	Year	Title	Type of study	Type of patients	Sample size	Sample type	Primary outcome
Sakamoto E, Kido R, Tomotake Y et al.	2018	Calprotectin and cross-linked N-telopeptides of type I collagen levels in crevicular fluid from implant sites with+ peri-implant diseases: a pilot study	Cross-sectional	Patients who received dental implants from 3 to 9 years ago, had healthy or diseased implants with peri-implant diseases.	n = 35	PICF	NTX levels in PICF samples were significantly higher from diseased sites than from healthy sites.
Alotaibi DH AM, Mezeid MS, Al-Azhari LA	2018	Potential biomarkers for peri-implantitis: a cross-sectional study of type I collagen levels in the sulcular fluid in relation to cross-linked n-telopeptide and calprotectin	Cross-sectional	Patients with a single dental implant in the previous 5-10 years with healthy or diseased sites..	n = 50	PISF	Positive correlation between bone loss rate and NTX. Thus NTX could be a potential biomarker for bone destruction in patients with peri-implantitis.
Friedmann A, Friedrichs M, Kaner D et al	2006	Calprotectin and cross-linked N-terminal telopeptides in peri-implant and gingival crevicular fluid	Longitudinal	Patients who received dental implants in previously augmented edentulous segments, 7 months after the grafting procedures took place.	n = 22	PICF, GCF	The amount of NTX was not statistically significant in the implant sites. Correlations between the amounts of GCF or PICF and NTX levels showed an increasing pattern.
Hall J, Britse AO, Jemt T, Friberg B et al.	2011	A controlled clinical exploratory study on genetic markers for peri-implantitis	Cross-sectional	Patients previously rehabilitated with dental implants attending scheduled implant maintenance sessions.	n = 14	PICF	The expression of TRAP was not significantly different between healthy implant and peri-implantitis groups, suggesting that sampling and qPCR analysis of PICF may not be a useful method for the assessment of ongoing bone resorption.
Hall J, Pehrson NG, Ekestubbe A et al.	2015	A controlled, cross-sectional exploratory study on markers for the plasminogen system and inflammation in crevicular fluid samples from healthy, mucositis and peri-implantitis sites	Cross-sectional	Patients previously rehabilitated with dental implants, all of whom were attending scheduled implant maintenance sessions.	n = 75	PICF	The expression of TRAP was not significant in any group. Seems unlikely that TRAP can be used for rapid assessment of ongoing bone degradation, except possibly in aggressive cases with large bone degradation rates.
Albeshri S, Alblaihess A, Niazy AA et al.	2018	Biomarkers as independent predictors of bone regeneration around biomaterials: a systematic review of literature	Systematic review	Humans and animals (sheep, rabbits, rats, mice, dogs) with varied biomaterial implants`	41 studies		The most specific and sensitive biomarker produced by bone resorbing osteoclasts was determined to be TRAP. In animal studies, TRAP significantly correlated with osteoclast-like activity wherein TRAP5b was detected early in the postoperative immunoassays.

Author	Year	Title	Type of study	Type of patients	Sample size	Sample type	Primary outcome
Swarup S, Sabharwal P, Meena M et al.	2022`	Calprotectin and n-telopeptide of type I collagen (NTx) as gingival crevicular fluid (GCF) biomarker in peri-implantitis patients	Cross-sectional	Healthy patients who received a dental implant within the last decade.	n = 35	PICF	The overall mean NTX value was significantly higher in sites suffering from peri-implantitis when compared with healthy locations.

Future recommendations

Despite the findings from Gursoy et al. in 2009 in subjects with periodontitis, saliva has demonstrated value in its role as a specimen in periodontal diagnostics, including the determination of the periodontal status of subjects in large-scale epidemiological studies. (34, 51-52) Therefore, there is potential to use saliva as a sample, alongside PICF, in detecting NTX-I and TRAP5b in peri-implantitis. Future research should conduct studies with greater sample size, and which have clearly defined diagnostic criteria to differentiate between peri-implant diseases. This would help to increase the accuracy of records of bone destruction biomarkers in each pathology. Also, long-term clinical studies would be the best study design to help further validate the biomarkers as independent determinants of bone turnover, which may require extra costs and an extended time period. Additional studies are essential to clarify the role, regulation, and function of these biomarkers in the pathogenesis of peri-implant disease and their distinct role in peri-implantitis.

Conclusion

NTX-I and TRAP5b demonstrate value in the diagnosis, prognosis, and clinical performance of bone loss related pathologies. In non-oral conditions, bone markers are assessed in either serum or urine. NTX is currently used to assess the anti-resorption effect of osteoporotic therapy on bone levels, and it is a useful tool in the prediction of disease progression in bone metastases. TRAP5b has shown to be a useful measure of bone destruction in patients with renal dysfunction. In periodontitis, NTX is a reliable marker of active bone resorption, with GCF being the most suitable sample type. In peri-implantitis, NTX-I has shown to be a promising clinical indicator to improve the clinical experience in the diagnosis of peri-implantitis. On the other hand, there has been conflicting research on TRAP's role in reflecting bone matrix destruction, however, the role of TRAP5b has not been investigated.

References:

1. Avila G, Galindo-Moreno P, Soehren S, Misch CE, Morelli T, Wang HL. A novel decision-making process for tooth retention or extraction. J Periodontol. 2009;80(3):476-91.

2. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. *J Clin Periodontol*. 2018;45 Suppl 20:S237-S45.

3. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. *J Clin Periodontol*. 2018;45 Suppl 20:S246-S66.

4. Lee CT, Huang YW, Zhu L, Weltman R. Prevalences of peri-implantitis and peri-implant mucositis: systematic review and meta-analysis. *J Dent*. 2017;62:1-12.

5. Carinci F, Romanos GE, Scapoli L. Molecular tools for preventing and improving diagnosis of peri-implant diseases. *Periodontol 2000*. 2019;81(1):41-7.

6. Johnson NW. Crevicular fluid-based diagnostic tests. Current opinion in Dentistry. 1991 Feb 1;1(1):52-65.

7. Theodoridis C, Doulkeridou C, Menexes G, Vouros I. Comparison of RANKL and OPG levels in peri-implant crevicular fluid between healthy and diseased peri-implant tissues. A systematic review and meta-analysis. *Clin Oral Investig*. 2021.

8. Duarte PM, Serrao CR, Miranda TS, Zanatta LC, Bastos MF, Faveri M, et al. Could cytokine levels in the peri-implant crevicular fluid be used to distinguish between healthy implants and implants with peri-implantitis? A systematic review. *J Periodontal Res*. 2016;51(6):689-98.

9. Rakic M MA, Radovanovic S, Petkovic-Curcin A, Vojvodic D, Tatic Z. Is the personalized approach the key to improve clinical diagnosis of peri-implant conditions? The role of bone markers. *J Periodontol*. 2020;91(7):859-69.

10. Belibasakis GN, Bostanci N. The RANKL-OPG system in clinical periodontology. *J Clin Periodontol*. 2012;39(3):239-48.

11. Halleen JM, Alatalo SL, Suominen H, Cheng S, Janckila AJ, Vaananen HK. Tartrate-resistant acid phosphatase 5b: a novel serum marker of bone resorption. *J Bone Miner Res*. 2000;15(7):1337-45.

12. Halleen JM, Ylipahkala H, Alatalo SL, Janckila AJ, Heikkinen JE, Suominen H, et al. Serum tartrate-resistant acid phosphatase 5b, but not 5a, correlates with other markers of bone turnover and bone mineral density. *Calcif Tissue Int*. 2002;71(1):20-5.

13. Darveau RP. Periodontitis: a polymicrobial disruption of host homeostasis. *Nat Rev Microbiol*. 2010;8(7):481-90.

14. Faot F, Nascimento GG, Bielemann AM, Campao TD, Leite FR, Quirynen M. Can peri-implant crevicular fluid assist in the diagnosis of peri-implantitis? A systematic review and meta-analysis. *J Periodontol*. 2015;86(5):631-45.

15. Greenblatt MB, Tsai JN, Wein MN. Bone Turnover Markers in the Diagnosis and Monitoring of Metabolic Bone Disease. *Clin Chem*. 2017;63(2):464-74.

16. Delucchi F, Canepa C, Canullo L, Pesce P, Isola G, Menini M. Biomarkers from Peri-Implant Crevicular Fluid (PICF) as Predictors of Peri-Implant Bone Loss: A Systematic Review. International journal of molecular sciences. 2023 Feb 6;24(4):3202.

17. Alotaibi DH AM, Mezeid MS, Al-Azhari LA. Potential biomarkers for peri-implantitis: A cross-sectional study of type I collagen levels in the sulcular fluid in relation to cross-linked n-telopeptide and calprotectin. *Ann Med Health Sci Res*. 2020;10(6):1158-62.

18. Hall J, Britse AO, Jemt T, Friberg B. A controlled clinical exploratory study on genetic markers for peri-implantitis. *Eur J Oral Implantol*. 2011;4(4):371-82.

19. Hall J, Pehrson NG, Ekestubbe A, Jemt T, Friberg B. A controlled, cross-sectional exploratory study on markers for the plasminogen system and inflammation in crevicular fluid samples from healthy, mucositis and peri-implantitis sites. *Eur J Oral Implantol*. 2015;8(2):153-66.

20. Herrmann M, Seibel MJ. The amino- and carboxyterminal cross-linked telopeptides of collagen type I, NTX-I and CTX-I: a comparative review. *Clin Chim Acta*. 2008;393(2):57-75.

21. Szulc P. Bone turnover: Biology and assessment tools. *Best Pract Res Clin Endocrinol Metab*. 2018;32(5):725-38.

22. Mira-Pascual L, Patlaka C, Desai S, Paulie S, Nareoja T, Lang P, et al. A Novel Sandwich ELISA for Tartrate-Resistant Acid Phosphatase 5a and 5b Protein Reveals that Both Isoforms are Secreted by Differentiating Osteoclasts and Correlate to the Type I Collagen Degradation Marker CTX-I In Vivo and In Vitro. *Calcif Tissue Int*. 2020;106(2):194-207.

23. Brown JE, Cook RJ, Major P, Lipton A, Saad F, Smith M, et al. Bone turnover markers as predictors of skeletal complications in prostate cancer, lung cancer, and other solid tumors. *J Natl Cancer Inst*. 2005;97(1):59-69.

24. Hirsh V, Major PP, Lipton A, Cook RJ, Langer CJ, Smith MR, et al. Zoledronic acid and survival in patients with metastatic bone disease from lung cancer and elevated markers of osteoclast activity. *J Thorac Oncol*. 2008;3(3):228-36.

25. Lipton A, Cook R, Saad F, Major P, Garnero P, Terpos E, et al. Normalization of bone markers is associated with improved survival in patients with bone metastases from solid tumors and elevated bone resorption receiving zoledronic acid. *Cancer*. 2008;113(1):193-201.

26. Habermann B, Eberhardt C, Feld M, Zichner L, Kurth AA. Tartrate-resistant acid phosphatase 5b (TRAP 5b) as a marker of osteoclast activity in the early phase after cementless total hip replacement. *Acta Orthop*. 2007;78(2):221-5.

27. Shidara K, Inaba M, Okuno S, Yamada S, Kumeda Y, Imanishi Y, et al. Serum levels of TRAP5b, a new bone resorption marker unaffected by renal dysfunction, as a useful marker of cortical bone loss in hemodialysis patients. *Calcif Tissue Int*. 2008;82(4):278-87.

28. Hannon RA, Clowes JA, Eagleton AC, Al Hadari A, Eastell R, Blumsohn A. Clinical performance of immunoreactive tartrate-resistant acid phosphatase isoform 5b as a marker of bone resorption. *Bone*. 2004;34(1):187-94.

29. Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, et al. Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Clin Periodontol*. 2018;45 Suppl 20:S162-S70.

30. Alfaqeeh SA, Anil S. Osteocalcin and N-telopeptides of type I collagen marker levels in gingival crevicular fluid during different stages of orthodontic tooth movement. *Am J Orthod Dentofacial Orthop*. 2011;139(6):e553-9.

31. Aruna G. Plasma levels of N-telopeptide of Type I collagen in periodontal health, disease and after treatment. *Dent Res J* (Isfahan). 2016;13(1):18-23.

32. Wilson AN, Schmid MJ, Marx DB, Reinhardt RA. Bone turnover markers in serum and periodontal microenvironments. *J Periodontal Res*. 2003;38(4):355-61.

33. Aruna G. Estimation of N-terminal telopeptides of type I collagen in periodontal health, disease and after nonsurgical periodontal therapy in gingival crevicular fluid: A clinico-biochemical study. *Indian J Dent Res*. 2015;26(2):152-7.

34. Gursoy UK, Kononen E, Huumonen S, Tervahartiala T, Pussinen PJ, Suominen AL, et al. Salivary type I collagen degradation end-products and related matrix metalloproteinases in periodontitis. *J Clin Periodontol*. 2013;40(1):18-25.

35. Harrington DJ. Bacterial collagenases and collagen-degrading enzymes and their potential role in human disease. *Infect Immun*. 1996;64(6):1885-91.

36. Becerik S, Afacan B, Ozturk VO, Atmaca H, Emingil G. Gingival crevicular fluid calprotectin, osteocalcin and cross-linked N-terminal telopeptid levels in health and different periodontal diseases. *Dis Markers*. 2011;31(6):343-52.

37. Almehmadi AH, Alghamdi F. Biomarkers of alveolar bone resorption in gingival crevicular fluid: A systematic review. *Arch Oral Biol*. 2018;93:12-21.

38. Becker ST, Beck-Broichsitter BE, Graetz C, Dorfer CE, Wiltfang J, Hasler R. Peri-implantitis versus periodontitis: functional diffe rences indicated by transcriptome profiling. *Clin Implant Dent Relat Res*. 2014;16(3):401-11.

39. Lindhe J LN, Karring T. *Clin Periodontol Imp Dent*. 5th ed. Oxford: Blackwell Munksgaard; 2008.

40. Sakamoto E, Kido R, Tomotake Y, Naitou Y, Ishida Y, Kido JI. Calprotectin and cross-linked N-telopeptides of type I collagen levels in crevicular fluid from implant sites with peri-implant diseases: a pilot study. *Int J Impl Dent*. 2018;4(1):26.

41. Bishop JA, Palanca AA, Bellino MJ, Lowenberg DW. Assessment of compromised fracture healing. *J Am Acad Orthop Surg*. 2012;20(5):273-82.

42. Friedmann A, Friedrichs M, Kaner D, Kleber BM, Bernimoulin JP. Calprotectin and cross-linked N-terminal telopeptides in peri-implant and gingival crevicular fluid. *Clin Oral Impl Res*. 2006;17(5):527-32.

43. Swarup S, Sabharwal P, Meena MK, Girdhar A, Ganjoo D, Khippal J. Calprotectin and N-telopeptide of Type I Collagen (NTx) as Gingival Crevicular Fluid (GCF) *Biomarker in Peri-Implantitis Patients*. Cureus. 2022;14(8):e28430.

44. Albeshri S, Alblaihess A, Niazy AA, Ramalingam S, Sundar C, Alghamdi HS. Biomarkers as Independent Predictors of Bone Regeneration around Biomaterials: A Systematic Review of Literature. *J Contemp Dent Pract*. 2018;19(5):605-18.

45. Leeming DJ, Alexandersen P, Karsdal MA, Qvist P, Schaller S, Tanko LB. An update on biomarkers of bone turnover and their utility in biomedical research and clinical practice. *Eur J Clin Pharmacol*. 2006;62(10):781-92.

46. Ram VS, Parthiban, Sudhakar U, Mithradas N, Prabhakar R. Bonebiomarkers in periodontal disease: a review article. *J Clin Diagn Res*. 2015;9(1):ZE07-10.

47. Kodama N, Nagata M, Tabata Y, Ozeki M, Ninomiya T, Takagi R. A local bone anabolic effect of rhFGF2-impregnated gelatin hydrogel by promoting cell proliferation and coordinating osteoblastic differentiation. *Bone*. 2009;44(4):699-707.

48. Taut AD, Jin Q, Chung JH, Galindo-Moreno P, Yi ES, Sugai JV, et al. Sclerostin antibody stimulates bone regeneration after experimental periodontitis. *J Bone Miner Res*. 2013;28(11):2347-56.

49. Wohlfahrt JC, Monjo M, Ronold HJ, Aass AM, Ellingsen JE, Lyngstadaas SP. Porous titanium granules promote bone healing and growth in rabbit tibia peri-implant osseous defects. *Clin Oral Impl Res*. 2010;21(2):165-7

50. Monjo M RJ, Ronold HJ, Taxt-Lamolle SF, Ellingsen JE, Lyngstadaas SP. Correlation between molecular signals and bone bonding to titanium implants. *Clin Oral Impl Res*. 2013;24(9):1035-43.

51. Kononen E, Paju S, Pussinen PJ, Hyvonen M, Di Tella P, Suominen-Taipale L, et al. Population-based study of salivary carriage of periodontal pathogens in adults. *J Clin Microbiol*. 2007;45(8):2446-51.

52. Range H, Leger T, Huchon C, Ciangura C, Diallo D, Poitou C, et al. Salivary proteome modifications associated with periodontitis in obese patients. *J Clin Periodontol*. 2012;39(9):799-806.

Geistlich

Prof. Ronald E. Jung - Switzerland

Reducing Risk and Stress in Modern Implant Dentistry

Hands-On workshop

Every dentist is confronted on a daily basis with the question: What to do with extraction sockets? The success in aesthetic implant dentistry depends on the correct decision-making process after tooth extraction. This workshop will provide practical and clinical information to make the right decisions between a) Alveolar Ridge Preservation (ARP), b) immediate implant placement and c) delayed or late implant placement. The advantages and the limitations of different techniques will be discussed.

A special focus will be on how to improve your aesthetic results with anterior implants and how to reduce risks. The scientific background and detailed clinical concepts of the L-shape Guided Bone Regeneration (GBR) and soft tissue management techniques will be presented and performed.

This workshop will provide you with practical information of all steps necessary to achieve an optical aesthetic and healthy result.

Topics to be covered:

- Basic overview of the healing sequence after dental extraction: hard tissue and soft tissue contributions to post-extraction ridge volume changes
- The role of biomaterials in preserving alveolar ridge dimensions
- Managing dehiscence and fenestration defects with GBR – long-term outcomes and clinical protocols
- The importance of soft tissue quality and quantity in long-term crestal bone stability, soft tissue integration, and peri-implant health
- Timing of soft tissue augmentation and considerations
- Soft tissue augmentation around dental implants using a volume stable collagen matrix
- Practical exercises on appropriate models and/or pig jaws:
  - L-shape GBR technique
  - Use of collagen matrix to increase width of keratinised mucosa
  - Use of volume stable collagen matrix to increase soft tissue thickness

Workshop Details:

Brisbane	**Thursday, 22nd August '24 (Registration 8.30am) 9.00am - 5.00pm**
Sydney	**Friday, 23rd August '24 (Registration 8.00am) 8.30am - 4.30pm**
Melbourne	**Saturday, 24th August '24 (Registration 8.00am) 8.30am - 4.30pm**

SAVE $100 WHEN REGISTERED BY 28TH JUN '24

Cost	**$1495 Catering provided**
CPD	**6 Scientific CPD hours**

All workshop materials provided, attendees are welcome to bring their own loupes.

6 CPD hours | Level 2 | Catering Provided | Pig Jaws

Register online now
Visit **www.geistlich.com.au/cpd**
Refer to the website for terms and conditions, and future events

straumann

STRAUMANN® EDUCATION AND ENABLEMENT

It is our mission to be the benchmark for professional training and continuing development in implant dentistry. We and our partners offer a comprehensive education program in all disciplines of implant dentistry, and with the latest technology available. This covers all aspects from tooth preservation to implant-borne restorations, as well as oral tissue regeneration – for all specialisations, on all skill levels.

→ DISCOVER OUR EDUCATION OFFERINGS

ITI International Team for Implantology

For more than 30 years, Straumann has enjoyed a close and fruitful relationship with its independent scientific partner, the International Team for Implantology (ITI).

Join the ITI Global Community
iti.org/community/become-a-member

Straumann Pty Ltd/Straumann New Zealand Limited
93 Cook Street, Port Melbourne VIC 3207, Australia
AU Toll Free 1800 660 330 **NZ Toll Free** 0800 408 370
Email marketing.au@straumann.com
www.straumann.com.au | www.straumann.co.nz

BioMin

Some products just work!
BioMin effectively reduces sensitivity[1].

90% confirm sensitivity reduction[2]

Internal fluorapatite tubular occlusion

Actively raises pH of saliva

Effective remineralising agent[3]

Vegan CPP-ACP alternative

Effective sensitivity relief:

BioMin's particles enter the open tubules and internally create an acid resistant fluorapatite occlusion. The outcome is a larger proportion of occluded tubules post acid attack for a greater reduction in sensitivity[4]

Clincial and consumer reviewed: PRODUCT REVIEW.COM.AU[2]

Performance supported by 20+ clinical papers and 600+ customer reviews

BioMinToothpaste.com.au/clinical

No.1 DENTAL PRODUCT Since 2019

Email: contact_us@LAZARK.com.au for more info and samples.

[1] Petrovic, Evaluation of Bioactive Glass Treatment for Dentine Hypersensitivity : A Systemic review 2023.
[2] BioMin F ProductReview.com.au Feb 1 2024. [3] Farooq, Efficacy of a novel fluoride bioglass 2019 [4]Data on file Queen Mary Univertisty Londan

Australian Periodontology Research Foundation Report 2024

I'm pleased to announce that after an absence of over a year, the APRF once again was able to support student research projects. The decision was made by the directors to expand the eligibility to all postgraduate students who undertake research in periodontology and surgical implant dentistry. This allowed MPhil and PhD students to apply in 2023.

The APRF would like to sincerely thank Colgate, the Australian Society of Periodontology and the Australian and New Zealand Academy of Periodontists for their ongoing and generous support.

The following students who were successful in 2023 are:

Alex Khominsky - The association between periodontal health, mental health and the subgingival microbiome

Chun Liu - Discovery the microbiome and proteome profiles of saliva-biofilm derived outer membrane vesicles cultured on 3D melt electrowritten poly(ε-caprolactone) scaffolds

Judd Sher - In vivo analysis of undisturbed peri-implant biofilm formation, composition, and growth in periodontally healthy and stable periodontitis patients

Jenny Wang - Cytokine profiles associated with extracellular vesicles in periodontal disease pre and post-periodontal therapy

Tian Xu - Novel nanoparticles of cerium-doped zeolitic imidazolate frameworks with anti-inflammatory capacity for periodontal regeneration

Jackie Yiu - Decontamination of titanium implant surface using novel nanocomposite activated by NIR laser

The Tom Higgins Memorial Student Publication Award for best publication was awarded to Dr Andrew Liaw for his paper "Salivary histone deacetylase in periodontal disease: A cross-sectional pilot study"

Applications for funding in 2024 are now open and should be sent to the Managing Director at the following email by 1st June 2024.
idarby@unimelb.edu.au

ASP NSW Branch Committee Details and Meetings

President: Dr Khai Nguyen

Secretary/Treasurer: Dr Wesley Wong

State Branch Councillor: Dr Robert Fell

Secretariat: Brooke Mcfarlane

Email: aspnsw@asp.asn.au

Meeting name: ASP (NSW) Dinner Meeting

Meeting date & time: 23 May 2024, 6:30pm

Meeting location: Swissotel, 68 Market Street, Sydney (above Myer Department Store)

Speakers: Dr Adam Rosenberg

Topics: Periodontal Endoscopy- Taking minimally invasive periodontal therapy to the next level.

Cost & other details: Members: free, Country member and guest additional costs.

Meeting name: ASP (NSW) Dinner Meeting

Meeting date & time: 15 August 2024, 6:30pm

Meeting location: Swissotel, 68 Market Street, Sydney (above Myer Department Store)

Speakers: Prof. Mehdi Rahimi

Topics: Immediate Implant Placement and Immediate Tooth replacement Therapy in the Aesthetic Zone: A Clinical Narrative

Cost & other details: Members: free, Country member and guest additional costs.

Meeting name: ASP (NSW) Full Day Meeting

Meeting date & time: Friday, October/ November 2024

Meeting location: TBA

Speakers: International Speaker to be confirmed

Topics: To be confirmed

Cost & other details:

ASP QLD Branch Committee Details and Meetings

President: Dr Marina Kamel

Secretary: Dr Miriam Lee

Treasurer: Dr Gabrielle Bou-Samra

Federal Councillor: A/Prof Ryan Lee

Email: aspqld@gmail.com

Meeting name: ASP (QLD) Dinner Meeting

Meeting date & time: Monday, 20 May 2024 - TBC

Meeting location:

Speakers:

Topics:

Cost & other details:

Meeting name: ASP (QLD) Dinner Meeting

Meeting date & time: Monday 29th July 2024

Meeting location: Location: The Inchcolm by Ovolo

Speakers: Dr Neil Meredith

Topics: Which, When, Where and Why?

Cost & other details: Fees: Free for members and $150 for non-members

ASP QLD Branch Committee Details and Meetings (cont'd)

Meeting name: ASP (QLD) Dinner Meeting

Meeting date & time: Monday 30th Sept 2024 -

Meeting location: Location: The Inchcolm by Ovolo

Speakers: Greg Seymour and Mary Cullinan

Topics: Research Medallion competition

Cost & other details: Fees: Free for members and $150 for non-members

Meeting name: ASP (QLD) Clinic Day

Meeting date & time: Friday 8th Nov 2024 -

Meeting location: Location: The Inchcolm by Ovolo

Speakers: Clinical day (speaker and topic TBC)

Topics:

Cost & other details: Fees: Free for members and $350 for non-members

ASP SA Branch Committee Details and Meetings

President: Dr Geoff Harvey

Secretary:

Treasurer:

State Branch Councillor: A/Prof Sushil Kaur

Email: aspsa2@gmail.com

Meeting name: ASP (SA) dinner meeting #2

Meeting date & time: Wednesday 19 June 2024. 6pm for 6:30pm start

Meeting location: ORSO, 36 Kensington Road, Rose Park SA

Speakers: Dr Brandon Pump, perio postgrad

Topics: Unravelling Periodontitis and Prognosis

Cost & other details: No additional charge for paid members/sponsors. $125 for single guest ticket

Meeting name: ASP (SA) Dinner Meeting #3

Meeting date & time: Wednesday 14 August 2024. 6pm for 6:30pm start

Meeting location: Lenzerheide, 146 Belair Road, Hawthorn SA

Speakers: Prof Ivan Darby

Topics: When to treat and when to refer patients with periodontitis

Cost & other details: No additional charge for paid members/sponsors. $125 for single guest ticket

Meeting name: ASP (SA) Dinner Meeting #4 and AGM

Meeting date & time: Wednesday 16 October 2024. 6pm for 6:30pm start

Meeting location: The Gallery, 30 Waymouth Street, Adelaide SA

Speakers: Dr Michael Stokes, Cardiologist

Topics: Cardiovascular Disease and Periodontitis

Cost & other details: No additional charge for paid members/sponsors. $125 for single guest ticket

ASP VIC Branch Committee Details and Meetings

President: Dr Larissa Ong

Vice President: Dr Alice Huynh

Secretary/Treasurer: Dr Eugene Sheftel

Branch Councillor: Dr Sarah Chin

Email: aspvic@gmail.com

Meeting name: ASP (VIC) Dinner Meeting

Meeting date & time: Date: 24th July 2024 Time: 6.00pm registration for a 6.30pm start

Meeting location: Woodward Conference Centre - 10th Floor, Melbourne Law, the University of Melbourne, 185 Pelham Street, Carlton VIC 3053

Speakers: Dr. Gary Yip (Periodontist)

Topics: The management of periodontally compromised posterior teeth: knowing when to hold and when to fold.

Cost & other details: RSVP: by 17th July 2024 with dietary requirements Cost: $180 (includes 3-course dinner) via EFT to BSB: 083026 Acc: 609430668. Free for ASP (Vic) members. CPD hours: 1.0

Meeting name: ASP (VIC) Dinner Meeting

Meeting date & time: Date: 20th November 2024 6.00pm registration for a 6.30pm start

Meeting location: Woodward Conference Centre - 10th Floor, Melbourne Law, the University of Melbourne, 185 Pelham Street, Carlton VIC 3053

Speakers: A/Prof Neil McGregor

Topics: Personalised periodontics: A multidisciplinary approach

Cost & other details: RSVP: by 13th November 2024 with dietary requirements Cost: $180 (includes 3-course dinner) via EFT to BSB: 083026 Acc: 609430668. Free for ASP (Vic) members. CPD hours: 1.0

ASP WA Branch Committee Details and Meetings

President: Dr Nish Bhargava

Secretary: Ms Jennine Bywaters

Treasurer: Dr Samy Francis

Federal Councillor: Dr Fritz Heitz

Email: aspwaperth@gmail.com

Meeting name: ASP (WA) Lecture and Hands-On Course

Meeting date & time: June 2024

Meeting location: TBC

Speakers: Dr Shayan Barootchi (TBC)

Topics: Soft tissue grafting

Cost & other details: TBC

Meeting name: ASP (WA) AGM and Lecture

Meeting date & time: August 22nd, 2024 at 6.30pm

Meeting location: ADA House, 54 Havelock St. West Perth

Speakers: Dr Wendy Gill

Topics: Communicating Periodontitis

Cost & other details: Free for members

Meeting name: ASP (WA) End of Year Dinner

Meeting date & time: November 15th or 22nd, 2024

Meeting location: Mandoon Estate, Caversham

Speakers: TBC

Topics: TBC

Cost & other details: TBC

AOS NSW Committee Details and Meetings

President: Dr Eugene Foo

Secretary: Dr Cecilia So

Treasurer: Dr Bruce Munroe

Federal Councillor: A/Prof George Pal

Admin/Secretariat: Heather Archer

Email: infonsw@aos.org.au

Meeting name: AOS (NSW) Half Day Meeting

Meeting date & time: Friday, 28th June 2024, 3.30pm

Meeting location: Dr Wendy Gill

Speakers: The View, 17 Blue Street, Sydney

Topics: Implant complications with a patient centred perspective

Cost & other details: Members: Free Guest $330 Register Online- https://nsw.aos.org.au/

Meeting name: AOS (NSW) Dinner Meeting

Meeting date & time: Tuesday, 13th August 2024, 6pm

Meeting location: Professor Iven Klineberg

Speakers: The View, 17 Blue Street, Sydney.

Topics: Implants In Children

Cost & other details: Members: Free Guest $143 Register Online- https://nsw.aos.org.au/

AOS QLD Committee Details and Meetings

President: Dr Peter LC Chen

Secretary: Dr Marina Kamel

Treasurer: Dr Jonathan Ng

General Committee: Dr Daniel Hu

Email: aosqld@gmail.com

Meeting name: AOS (QLD) Dinner Meeting

Meeting date & time: Wednesday 21st of April 2024

Meeting location: TBC

Speakers: Professor Neil Meredith

Topics: "Real World Clinical and Technical Workflows for Implant Dentistry"

Cost & other details: Members: Free
Non Members:$150
Email aosqld@gmail.com to register

Meeting name: AOS QLD Half Day Meeting

Meeting date & time: Thursday 9th of May 2024, 1pm to 6pm

Meeting location: The Inchcolm by Ovolo

Speakers: Dr Andrea Agnini (ITALY)

Topics: "A Working Approach to Digitizing the Implant Workflow in the Aesthetic Zone"

Cost & other details: Members: Free
Non Members:$150
Email aosqld@gmail.com to register

Meeting name: AOS (QLD) Dinner Meeting

Meeting date & time: Wednesday 19th of June 2024

Meeting location: TBC

Speakers: Mr Julio Rojas, Medical Engineer

Topics: "Going completely digital for full-arch restorations. A look at the revolution in full-arch workflows and the importance of controlled end-to-end restorative processes."

Cost & other details: Members: Free
Non Members:$150
Email aosqld@gmail.com to register

AOS SA Committee Details and Meetings

President: Dr Ramon Baba

Secretary: Mr Hab Awwad

Treasurer:

Federal Councillor: Dr Ramon Baba

Admin/Secretariat: Ms Francine Poole

Email: infoaos.sa@gmail.com

AOS Victoria Committee Details and Meetings

President: Dr Angelos Sourial

Secretary: Dr Paul Fagliarone

Treasurer: Dr Betty Lisa Matthews

Federal Councillor: Dr Gabriel Rodriguez-Ortiz

Committee Members: Dr Brandon Krapf, Dr Larissa Ong, Dr Philip Ho,Dr Fady Tossoun, Dr David Laskey, Mr Michael Qiu

Admin/Secretariat: Ms Bella Cherkasskaya

Email: infovic@aos.org.au aosvic@gmail.com

Meeting name: AOS (VIC) Dinner meeting and online broadcasting

Meeting date & time: 7-May-24

Meeting location: Royal South Yarra Lawn Tennis Club 310 Williams Road North, Toorak 3142

Speakers: Dr Werner Bischof Periodontist; Dr Gidon Fixler Prosthodontist

Topics: Predicting and mitigating risk in implant prosthodontics: how far have we come?
Planning to avoid complications.
Treatment planning concepts. Risk assessment.
Restorative and Surgical aspects

Cost & other details: Members- free, Students - $55, Online members (dinner) - $110, Non-members - $190

Meeting name: AOS (VIC) Dinner meeting and online broadcasting

Meeting date & time: 6-Jun-24

Meeting location: Royal South Yarra Lawn Tennis Club 310 Williams Road North, Toorak 3142

Speakers: Dr Stephen Chan and Dr Anthony Dickenson.

Topics: "20:20 hindsight: What we have learned over the last 30 years"

Cost & other details: Members- free, Students - $55, Online members (dinner) - $110, Non-members - $190

Meeting name: AOS (VIC) Dinner meeting and online broadcasting

Meeting date & time: Last week of July 2024 (25th of July)

Meeting location: Royal South Yarra Lawn Tennis Club 310 Williams Road North, Toorak 3142

Speakers: Dr Varun Gang Prosthodontist and Dr Sarah Byrne Periodontist

Topics: TBC

Cost & other details: Members- free, Students - $55, Online members (dinner) - $110, Non-members - $190

Meeting name: AOS (VIC) Meeting

Meeting date & time: TBA

Meeting location: Zoom

Speakers: Dr Gabriel Rodrigues Ortiz - Periodontist Melbourne.

Topics: How to integrate the implants to your dental practice. Where to start and what to do if you want to do implants?

Cost & other details: Members- free, Students - $0, Online members - $0, Non-members - $50

AOS WA Committee Details and Meetings

President: Dr Tony Strangio
Secretary: Dr Andrew Ziepe
Treasurer: Dr Richard Williams
Federal Councillor: Dr Roy Sarmidi
Email: aoswa2018@gmail.com

Meeting Name: AOS WA Dinner Meeting
Meeting date & time: Friday, 28th of June 2024 @ 6.30pm
Meeting location: TBA
Speakers: Prof Roy Judge
Topics: Novel Implants and the implant/abutment connection
Cost & other details: TBA

Find out online...

Meeting details are also available online:

Australian Society of Periodontology
https://www.asp.asn.au/
Or check with your state branch Secretary/Secretariat for further details.

Australasian Osseointegration Society
https://www.aos.org.au/
Or check with your state branch Secretary/Secretariat for further details.

VOLUME 8 | Issue 1 | April 2024 | ISSN 2209-7627

The Australian Journal of Periodontology and Implant Dentistry Limited

The Official Journal of the Australian Society of Periodontology and the Australasian Osseointegration Society

Australasian Osseointegration Society limited

www.ajpid.org.au