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Biomimetic Implant Surface Functionalization with Concentrated Platelet-Rich Fibrin: An Invitro Study

Aparna Ayyalasomayajula [1,a], Muthukumar Santhanakrishnan[1,b,*], Sri Vidhya Marimuthu [2,c], Ravindranath Dhulipalla[3,d], Ramanarayana Boyapati[3,e]

[1]*Department of Periodontology and Oral Implantology, Sri Ramachandra Dental College and Hospital, Chennai*
[2] *Department of Periodontology and Oral Implantology, Sri Venkateshwaraa Dental College, Puducherry*
[3]*Department of Periodontology and Oral Implantology, Sibar Institute of Dental Sciences, Guntur*
**Corresponding author*

Research Article

History

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ABSTRACT

Objective: With high long-term survival and success rates, implant-supported oral rehabilitation has progressively expanded the treatment options available to edentulous patients. However, osseointegration may be impacted by certain medical conditions. In order to enhance osseointegration and encourage fibrin adherence, surfaces with particular micro- and nanotopographies and biomimetic properties have been developed. Recently, there has been interest in a potential strategy that involves using the patient's autologous blood to functionalise the implant surface just prior to placement. The objective of this in vitro study is to analyse the physiochemical characterization of three commercially available dental implant surfaces and evaluate the interaction between the implant surface and C-PRF

Materials and Methods: Three commercially available implants with different macro-morphology and surface treatments - Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® were analysed for physiochemical characterization and biofunctionalization using C-PRF Field emission scanning electron microscope (FESEM)

Results: All the surfaces appeared visibly rough to varying degrees under FESEM with EDS. The topographies were qualitatively different for all three implant systems- Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® that were analysed, and showed different elemental compositions. Every dental implant immersed in C-PRF had a fibrin mesh covering it. Nonetheless, distinct noncontact regions were noted, and the fibrin orientation varied across all implant surfaces.

Conclusions: There are notable differences in the initial interaction between the fibrin network and various implant surfaces. The therapeutic significance of these findings in the osseointegration process of dental implants requires further investigation.

Keywords: Dental Implants, Platelet concentrates, Biomimetic functionalization, Osseointegration, Concentrated Platelet Rich Fibrin(C-PRF)

[a] *aparnasrinivas10@gmail.com* *0000-0002-3483-114X*
[b] *muthukumars@sriramachandra.edu.in* *0000-0001-9688-1516*
[c] *drsrividhyavidhu@gmail.com* *0009-0001-5071-8358*
[d] *ravident69@gmail.com* *0000-0003-4103-455X*
[e] *dr.ramanarayana@gmail.com* *0000-0002-9196-0183*

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Introduction

Implant-supported oral rehabilitation has improved treatment options for edentulous patients with high long-term survival and prosperity rates. The success rate of dental implants can be impacted by several clinical conditions that can impede the osseointegration process. Patient cognate factors such as physiological and pathological changes occurring in conditions like ageing, low bone density, smoking, diabetes mellitus, osteoporosis, bisphosphonate and radiotherapy jeopardize bone health thereby affecting the quality and quantity of bone available for receiving dental implants, as a result, implant failures can develop early in the peri-implant bone healing process in these patients.[1,2] The formation of a stable fibrin clot in contact with the implant surface, which accommodates a provisional scaffold for the migration of developing osteogenic cells towards the implant surface, is a critical phase of the healing process.[3] Consequently, materials with biomimetic properties and categorical micro and nano topographies have been created to enhance osseointegration and encourage fibrin adhesion.

Various approaches have been used to improve and help accelerate the osseointegration process without compromising tissue integration or mechanical outcomes.[4,5] The implant topography plays a critical role during the early stages of bone-to-implant contact (BIC). The physiochemical properties of implants, including as surface topography, surface wettability, and energy, have been thoroughly investigated and altered to improve osseointegration.[6–8] The initial interactions, immediately after implant surgery, take place between the host cells and the implant surface atoms through the adsorbed proteins and not the material bulk itself. Thus, modifying

the surface properties of dental implants to influence the events occurring at the implant-tissue interface has been the focus of profound research over the last decades. As a result, there are a variety of implant systems that have different implant surfaces are currently available for the dental market. Altering the surface topography is one of the most commonly used surface modification techniques for dental implants. Currently, the SLActive surface, laser machined surface (LMS) and nanotextured surface topography with trabecular pattern have gained interest.

The SLA surface is created by using coarse grit of 0.25–0.5 mm corundum grit at a pressure of 5 bar and then acid-etching. SLActive surface is also produced via the same sandblasting and acid etching technique, and undergoes a nitrogen-protected rinse to prevent air exposure before being stored within a sealed glass tube filled with isotonic NaCl solution.[9] Laser-Lok microchannels, a series of cell-sized circumferential channels generated via laser ablation, create consistently sized microchannels optimal for osteoblast and fibroblast attachment and organization, further enhanced by a repeating nanostructure increases surface area and facilitate the interdigitation of cell pseudopodia and collagen microfibrils with the Laser-Lok surface.[10] The Laser-Lok surface has been characterized by a physiological response that involves inhibiting epithelial down-growth and connective tissue attachment.[11] Trabecular metal material is a three-dimensional, highly biocompatible material with up to 80 per cent porosity and a structure and function comparable to cancellous bone. Made from tantalum, the trabecular metal material is fabricated utilizing a proprietary vapour deposition process.[12]

In addition to methods that involve surface topography changes, other biomimetic strategies have been investigated that use materials like bone morphogenetic proteins (BMPs), hydroxyapatite (HA), calcium phosphate, and growth factors to promote osteoinduction, osteoconduction, and osteogenesis. These strategies can be used to functionalise implant surfaces and encourage osseointegration, particularly in medically compromised individuals.[13] Recently, there has been growing interest in an alternative approach that uses the patient's autologous blood to functionalise the implant surface right before implantation.

One common way to obtain bioactive compounds from a patient's blood is through autologous blood concentrates.[14] High platelet and growth factor concentrations added to surgical sites can promote both soft and hard tissue healing and make it easier to attain favourable and consistent treatment results.[15] The L-PRF methodology was recently used to create the Concentrated PRF (C-PRF), which concentrates on removing just liquid material from the tiny buffy coat. It is believed that C-PRF produces extremely high levels of platelets and leukocytes.[16,17] Two proteins, fibronectin and vitronectin, have a significant role in platelet function and later cell adhesion to the extracellular matrix during the healing process.[18,19] Furthermore, platelet concentrates can produce growth factors (GF) that support angiogenesis, cell migration, and differentiation, such as vascular endothelial growth factor (VEGF), transforming growth factor 1 (TGF1), and platelet-derived growth factor-AB (PDGF-AB).[20,21] Platelet concentrations may therefore be a useful means of achieving a biomimetic autologous functionalisation of implant surfaces, which would encourage osseointegration.[22]

Therefore, PRF biofunctionalization of implant surfaces may play a crucial part in encouraging and quickening osseointegration. Although platelet concentrates are frequently used in bone regeneration processes, little is known about how they affect implant osseointegration. Images at higher magnification can be seen with a Field emission scanning electron microscope (FESEM).[23]

The aim of this in vitro study was to examine the physiochemical characteristics of three commercially available dental implant surfaces and evaluate their interaction with C-PRF using FESEM analysis.

Material and Methods

Ethical Considerations

Informed consent was obtained according to guidelines on human research adopted by the Institutional Ethics Committee, Sri Ramachandra Institute of Higher Education and Research, Chennai which approved the performance of this study after fulfilling the requirements of the committee with code CSP/21/NOV/102/588.

Exclusion Criteria:

- Patients with systemic diseases
- Smokers
- Patients consuming alcohol
- Pregnant and lactating women
- Patients with blood dyscrasias
- Patients who have consumed antibiotics within the last three months.

Methods of Research:

Three commercially available implants with different macro-morphology and surface treatments - Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok® were analysed for physiochemical characterization and biofunctionalization using C-PRF.

Phase 1: Physiochemical Characterization

The micro and nano topography and the Chemical composition of the Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok® implants were quantitatively analysed using the Field emission scanning electron microscope (FESEM) with energy dispersive X-ray spectrometer (EDS), (Thermo Scientific™ Quattro ESEM, USA) (Figure 1). Next, the water and solvent contact angles of the three commercially available implants were determined using a contact angle meter (sessile drop technique) KYOWA DMs 40 (Figure 2), half-angle method fitting, and FAMAS add-in software. The solvent droplet

range on the implant surface was 0.5–2 mL.[24] By measuring the contact angle of three probe liquids—water, ethylene glycol, and hexadecane—the Kitazaki Hata theory was used to determine the samples' solid surface free energy.[25]

Phase Ii: Preparation of Liquid Platelet Concentrate (C-Prf):

A healthy donor's venous blood was drawn from the antecubital fossa by a phlebotomist using 9 ml noncoated vacutainer tubes devoid of anticoagulants. The obtained samples were centrifuged for three minutes at about 700 RCF. After centrifuging the collected samples at 700 RCF for 3 minutes, C-PRF was aspirated with a sterile syringe and transferred immediately to Eppendorf tubes (Figure 3).

Dental Implant Processing

The surfaces of three commercially available dental implants (Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok®) are obtained through specific manufacturing techniques were analysed. At room temperature, the implants were completely submerged in concentrated platelet-rich fibrin for 60 minutes. After 60 minutes, the implants were gently removed from C-PRF, preserving the fibrin clot that was adhered to them. Immediately, 2% glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.4) was used to fix the samples.8 Using a critical point dryer and sputter coater, the specimens were prepared before being analyed with a Field Emission Scanning Electron Microscope (FESEM) (Figure-4).

***Figure 1**. Quantitative analysis of surface topography using the FESEM with EDS*

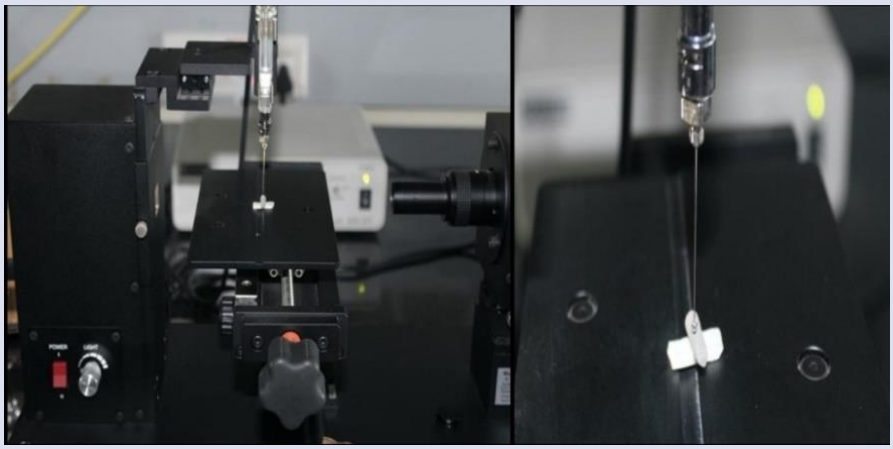

***Figure 2.** Surface wettability measurement using contact angle meter (sessile drop technique) KYOWA DMs-40, using half-angle method fitting and by FAMAS add-in software*

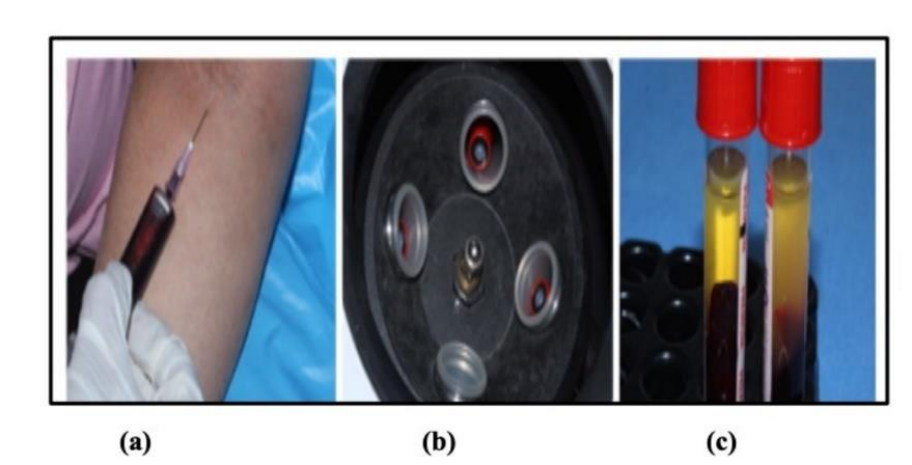

Figure 3. *a – Blood collected by phlebotomist; b- Centrifugation at 700 RCF for 3 minutes; c- Concentrated platelet rich fibrin.*

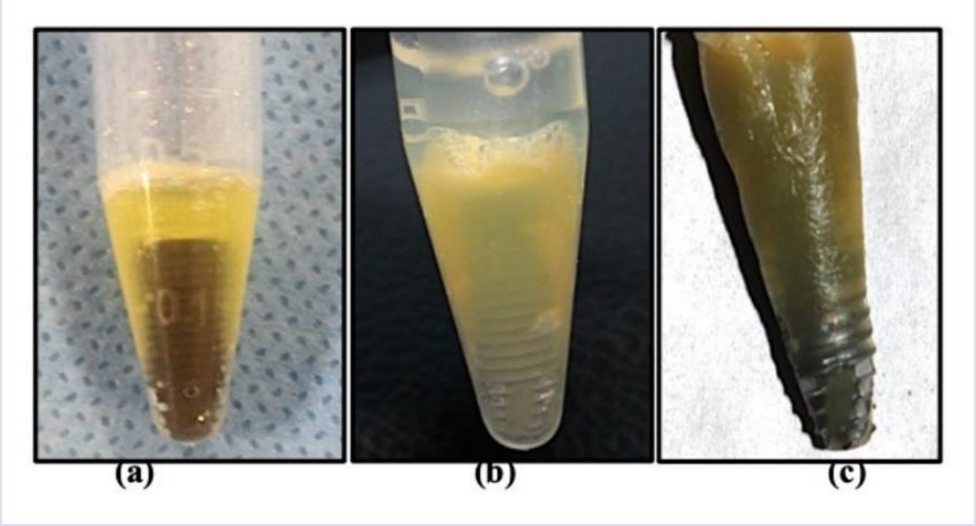

Figure 4*. a – Implant immersed in C-PRF; b- Sample fixed immediately in 2% glutaraldehyde in 0.1 M sodium cacodylate buffer; c- Prepared specimen using a critical point dryer and sputter coater for an analysis with FESEM*

Results

Physiochemical Characterization

Surface topography was visualized using a field emission scanning electron microscopy and the differences in the implant collar and body topography were assessed at varying magnifications- 1mm, 100µm, 50 µm, 30 µm, 10 µm and 5 µm respectively. All the surfaces appeared visibly rough to varying degrees under FESEM. The topographies were qualitatively different for all three implant systems- Straumann® BLX Roxolid®(Figure-5), Zimmer® Trabecular Metal™(Figure-6), and Laser-Lok®(Figure-7) that were analysed. The Straumann® BLX Roxolid®(fig-5), implant surface displayed irregularities, with many depressions and small indentations with numerous pores, as a result of the grit blasting and acid treatment procedure. The Zimmer® Trabecular Metal™(Figure-6) surface exhibits a faceted, granular morphology related to the CVD whereas the machined Laser-Lok®(Figure-7) surface showed a more uniform microtextured topography. The elemental chemical spectra obtained from FESEM EDS analysis of the implant surfaces at the collar and body region are shown in Figure 8, Table 1. The Zimmer® Trabecular Metal™ surface showed peaks associated with tantalum(Ta) and titanium (Ti), along with trace amounts of aluminum (Al), calcium (Ca), sodium (Na), carbon (C), and oxygen (O), whereas the Straumann® BLX Roxolid® showed peaks associated with titanium (Ti), and traces of sodium (Na), carbon (C), aluminium (Al) and zirconium (Zr). The Laser-Lok® surface showed peaks associated with titanium (Ti), along with aluminium (Al) and traces of calcium (Ca), carbon (C), iron (Fe) and nickel(Ni). Table 1 summarizes the element content of the implant surfaces.

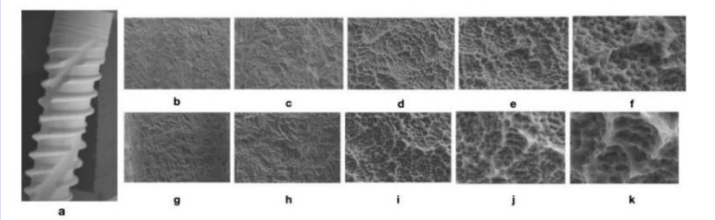

Figure 5. *FESEM image of Straumann® BLX Roxolid®, a- BLX Roxolid® 1 mm magnification, b- implant collar: 100 µm, c- implant collar:50 µm, d- implant collar:30 µm, e- implant collar:10 µm, f- implant collar: 5 µm, g- implant body: 100 µm, h- implant body:50 µm, i- implant body:30 µm, j- implant body: 10 µm, k- implant body: 5 µm*

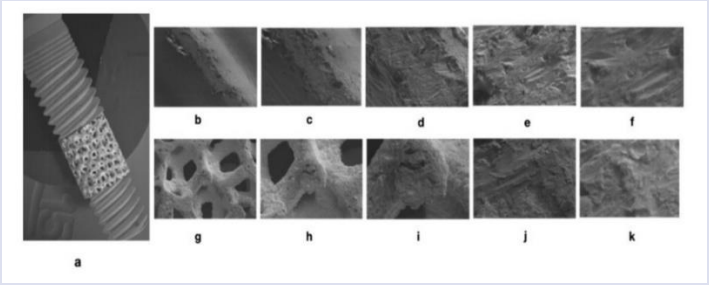

Figure 6. *FESEM image of Zimmer® Trabecular Metal™, a- Trabecular Metal™ 1mm magnification, b- implant collar: 100 µm, c- implant collar:50 µm, d- implant collar:30 µm, e- implant collar:10 µm, f- implant collar: 5 µm, g- implant body: 100 µm, h- implant body:50 µm, i- implant body:30 µm, j- implant body: 10 µm, k- implant body: 5 µm*

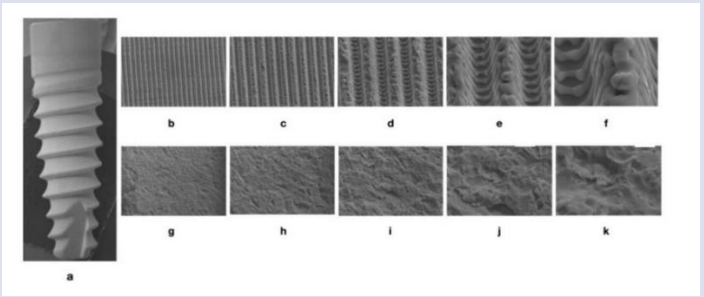

Figure 7. *a – Implant immersed in C-PRF; b- Sample fixed immediately in 2% glutaraldehyde in 0.1 M sodium cacodylate buffer; c- Prepared specimen using a critical point dryer and sputter coater for an analysis with a FESEM*

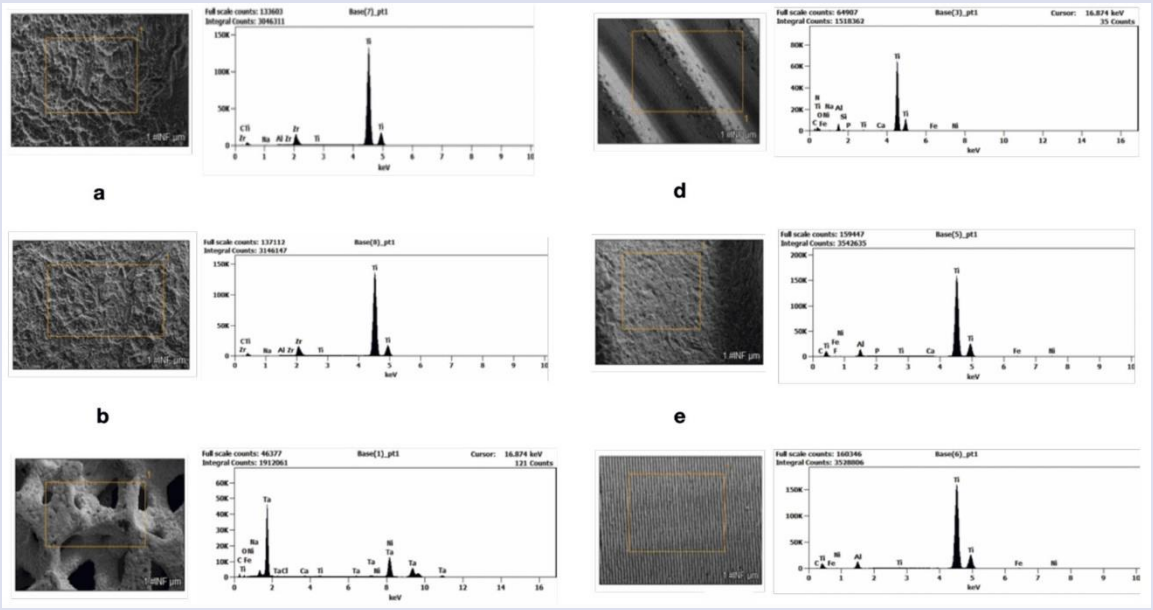

Figure 8. *FESEM images with EDS:- a: FESEM with EDS image of Straumann® BLX Roxolid®(body), b: FESEM with EDS image of Straumann® BLX Roxolid®(collar), c: FESEM with EDS image of Zimmer® Trabecular Metal™ (body), d: FESEM with EDS image of Zimmer® Trabecular Metal™ (collar), e: FESEM with EDS image of Laser-Lok® (body), f: FESEM with EDS image of Laser-Lok®(collar)*

Table 1. *Element composition of Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™ and Laser-Lok® implant surfaces (EDS)*

Straumann® BLX Roxolid®

Weight %- collar

	C	Na	Al	Ti	Zr
Base (7)_pt1	0.44	0.10	0.13	88.25	11.09

Weight % - body

	C	Na	Al	Ti	Zr
Base (8)_pt1	0.44	0.05	0.09	88.21	11.20

Zimmer® Trabecular Metal™

Weight % - collar

	C	N	O	Na	Al	Si	P	Ca	Ti	Fe	Ni
Base (3)_pt 1	3.6 3	5.0 5	14.2 1	0.1 7	4.0 8	0.2 0	0.1 0	0.0 9	72.0 0	0.3 1	0.1 5

Weight % - body

	C	O	Na	Cl	Ca	Ti	Fe	Ni	Ta
Base(1)_pt1	4.97	3.27	0.14	0.22	0.13	0.22	0.31	0.71	90.04

Laser-Lok®

Weight % - collar

	C	Al	Ca	Ti	Fe	Ni
Base(5)_pt1	0.52	5.40	0.07	93.50	0.25	0.11

Weight % - body

	C	Al	Ti	Fe	Ni
Base(6)_pt1	0.58	4.91	94.09	0.31	0.12

Surface Energy and Surface Wettability

Table 2 shows the results of the contact angle measurements. The Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, and Laser-Lok® implant surfaces displayed varying results, with the contact angles ranging from 0.2° to 130.5°. The Straumann® BLX Roxolid® (Figure 9) surface exhibited consummate wetting, composing a layer of dihydrogen monoxide across the surface, with a contact angle

approaching virtually zero (mean value of 0.50) indicative of a profoundly hydrophilic surface. The mean contact angle quantification value of Laser-Lok® (Figure 10) was 21.6, whereas the mean contact angle measurement of Zimmer® Trabecular Metal™ (Figure 11) was 130.0 suggestive of a highly hydrophobic surface. The surface free energy of all the implant surfaces is summarised in Table 3. Utilising the Kitazaki Hata theory, the surface energy of the Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® implant surfaces was determined to be 27.6, 27.5, and 12.7, respectively, by measuring the contact angle of three probe liquids: water, ethylene glycol, and hexadecane.

Table 2. *Contact angle using sessile drop technique*

Implant	C.A.(deg) collar	C.A.(deg) body	C.A(deg)AVG
Roxolid solid	0.2	0.6	0.5
laser Lok	30.7	12.5	21.6
trab	129.5	130.5	130.0

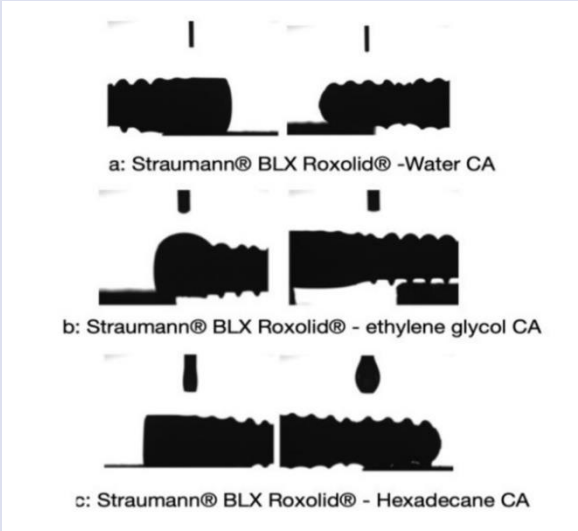

Figure 9. *Contact angle meter images of Straumann® BLX Roxolid®*

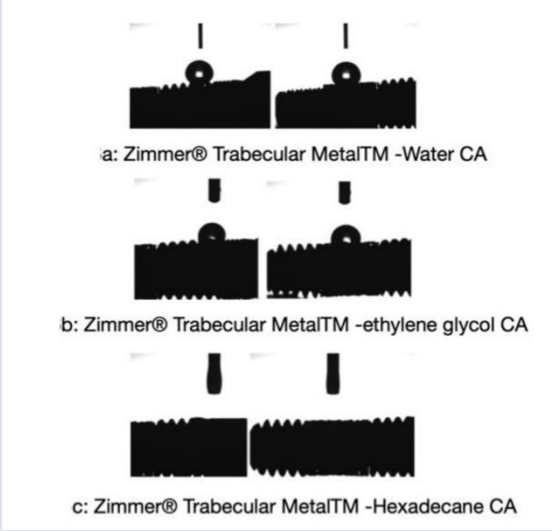

Figure 10. *Contact angle meter images of Zimmer® Trabecular Metal™*

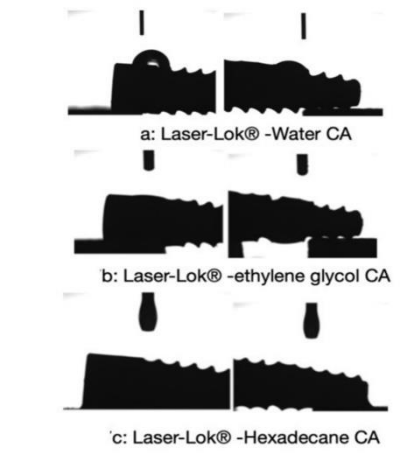

Figure 11. *Contact angle meter images of Laser-Lok®*

Table 3. *Surface free energy- Kitazaki-Hata method*

S.NO	Implant	Probe liquid	C.A.(deg.)Avg.	Probe liquid	C.A.(deg.)Avg.	Probe liquid	C.A.(deg.) Avg.	d (Kitazaki-Hata)
1	Roxolod solid	water	0.5	ethylene glycol	0.6	n- hexadecane	0.8	27.6
2	Laserlok	water	21.6	ethylene glycol	0.2	n- hexadecane	0.1	27.5
3	Trab	water	130.0	ethylene glycol	106.0	n- hexadecane	0.5	12.7

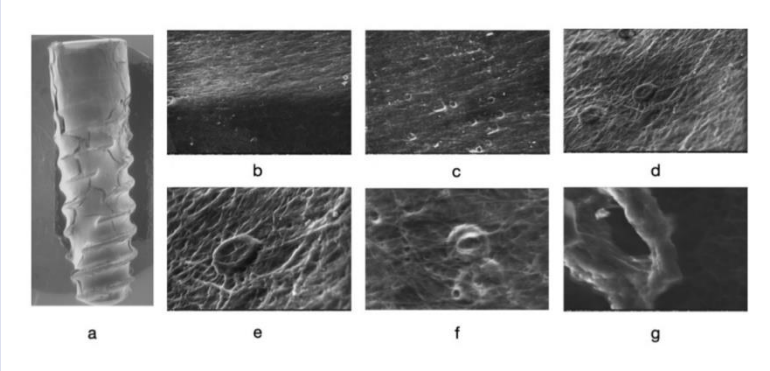

Figure 12. *FESEM images of C-PRF coated Straumann® BLX Roxolid® implant; a- BLX Roxolid® 1mm magnification, b- 100 µm magnification, c- 50 µm magnification, d-30 µm magnification, e-:10 µm magnification, f- 5 µm magnification, g- 3 µm magnification*

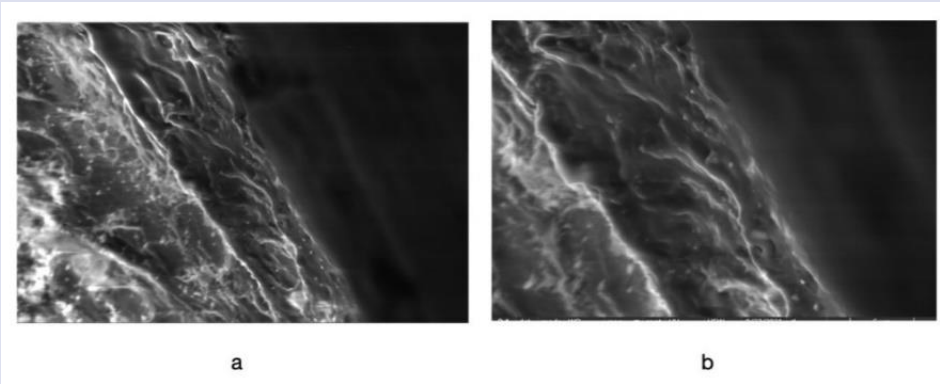

Figure 13. *Cross- section of C-PRF coated Straumann® BLX Roxolid® implant*

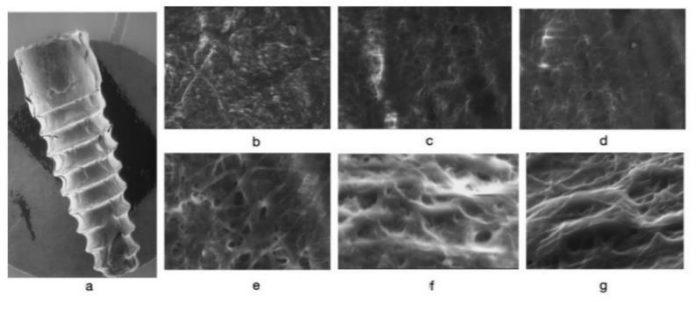

Figure 14. *FESEM images of C-PRF coated Laser-Lok® implant; a- Laser-Lok® 1mm magnification, b- 100 µm magnification, c-50 µm magnification, d- 30 µm magnification, e- 10 µm magnification, f- 5 µm magnification, g- 3 µm magnification*

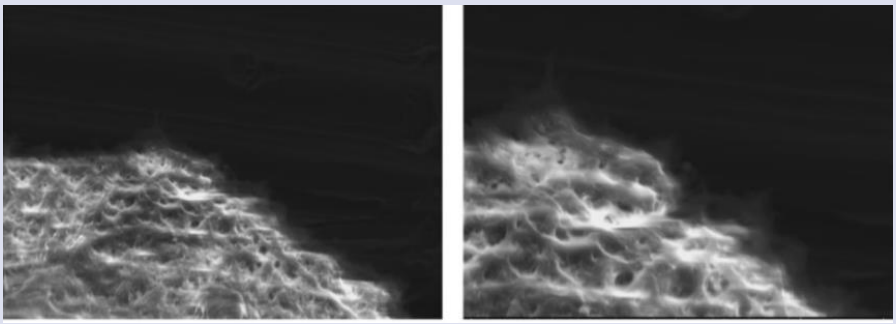

Figure 15. *Cross- section of C-PRF coated Laser-Lok® implant*

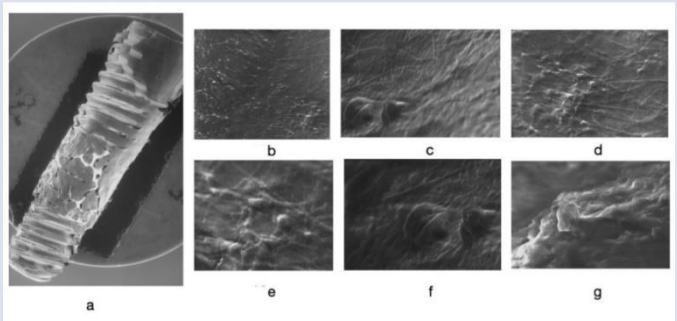

Figure 16. *FESEM images of C-PRF coated Zimmer® Trabecular Metal™ implant, a- Trabecular Metal™ 1mm magnification, b- 100 µm magnification, c- 50 µm magnification, d- 30 µm magnification, e- 10 µm magnification, f- 5 µm magnification, g- 3 µm magnification*

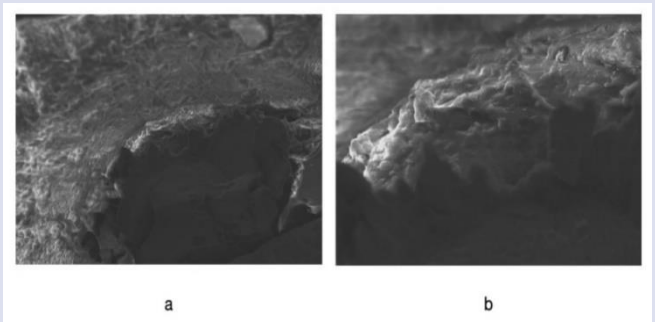

Figure 17. *Cross-section of C- PRF coated Zimmer® Trabecular Metal™ implant*

Biomimetic Functionalization with C-Prf Macroscopic Observation

Macroscopic visual examinations revealed the production of bubbles after submerging the implants in C PRF and these bubbles were cognate with areas without fibrin covering after 60 minutes in the case of Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™ and Laser-Lok® surfaces.

FESEM Image Interpretation

At both low and high magnification, significant differences were seen in all of the implant surfaces coated with C-PRF. In contrast to the Straumann® BLX Roxolid® and Laser-Lok® surfaces, which had a uniform and thick layer of fibrin covering the entire implant surface, the Zimmer® Trabecular MetalTM implant surface displayed crucial zones devoid of fibrin coverage (Figure 16a) (Figure 12a, 14a).

Furthermore, compared to the Straumann® BLX Roxolid® and Laser-Lok® surfaces, which had thicker and denser fibrin fibres running towards the implant surface, the Zimmer® Trabecular MetalTM implant surface showed a thinner fibrin layer with fewer fibrin fibres running towards the implant surface. Additionally, compared to the Zimmer® Trabecular MetalTM and Laser-Lok® surfaces, the Straumann® BLX Roxolid® surface showed a greater number of blood cells caught within the fibrin mesh (Figure 12).

On the Straumann® BLX Roxolid® surface, the fibrin fibres were orientated more perpendicularly to the implant surface (Figure 15, 17) than on the Laser-Lok® and Zimmer® Trabecular MetalTM surfaces, where they ran primarily parallel to the implant surface (Figure 13). With bigger diameter fibres, it was also seen that the Laser-Lok® and Straumann® BLX Roxolid® surfaces had a higher density and quantity of fibres being inserted and attached to the implant surface.

Discussion

In certain conditions, such as poorly controlled diabetes, low bone density, tobacco use, bisphosphonate medication, and radiation therapy, osseointegration is considerably less predictable, even though implant-supported oral rehabilitation has significantly improved treatment strategies for edentulous patients and demonstrated high long-term survival and success rates. Even with methods like aseptic surgical settings, optimised surgical implant procedures, and expedited postoperative care, a significant portion of implant failures happen in the early stages of peri-implant bone healing because of the patients' poor integration with nearby bone tissue.[26]

The formation of a stable fibrin clot in contact with the implant surface is an essential step in osseointegration because it provides a temporary scaffold for the migration of developing osteogenic cells to the implant surface. If osseointegration is not hastened, implants are susceptible to encapsulation by fibrotic tissue, a condition known as the foreign body reaction.[27] The presence of fibrotic tissue at the bone-implant contact often hinders implant attachment and performance. Materials with particular micro- and nano-topographies and biomimetic properties have been developed to promote fibrin adhesion and enhance osseointegration. Even though dental implants with surface microtopography have become the standard of care, only a small number of commercially available dental implants have micro-nano-textured surfaces, and biomimetic implant functionalisation techniques are not yet available for clinical usage.[28]

Using platelet concentrates is one of the more feasible and reliable ways to accomplish a biomimetic autologous functionalisation of implant surfaces to enhance osseointegration. There is currently a lack of research on the data supporting the usage of platelet concentrates in connection with implant osseointegration. Only two studies assessing the function of leukocyte- and platelet-rich fibrin (L-PRF) products for biomimetic implant surface functionalisation have been published in the literature thus far.[8,28] The goal of the current study was to assess the effects and interactions of applying concentrated platelet-rich fibrin (C-PRF) to several commercially available implant surfaces.

The present investigation used three commercially available implant surfaces: Laser-Lok®, Zimmer® Trabecular MetalTM, and Straumann® BLX Roxolid®. The SLActive® surface of the Straumann® BLX Roxolid® is made using the same initial manufacturing process as SLA. This process includes sandblasting with large grit, acid etching to create the ideal topography for bone cells to adhere to, conditioning in nitrogen, and instant preservation in an isotonic saline solution. In contrast to other traditional titanium implants that are hydrophobic, this preserves its high surface energy, which would otherwise be lost as a result of reaction with the atmosphere, and the cell behaviour on its hydrophilic surface encourages blood coagulation and higher expressions of bone-specific differentiation factors.[29,30]

However, Laser-Lok® uses laser ablation technology to create uniform microchannels, unlike grit-blasted and/or acid-etched implants that yield uneven surfaces. There has already been evidence of a physiological reaction to the Laser-Lok surface, including connective tissue attachment and prevention of epithelial downgrowth. Only the Laser-Lok surface has demonstrated successful soft tissue attachment in addition to osseointegration, despite random surfaces exhibiting greater osseointegration than machined surfaces.[11]

The Zimmer® Trabecular MetalTM is a porous material with a structure similar to cancellous bone. It is made of porous tantalum with a textured surface that promotes osseointegration and improves initial stability by serving as an osteoconductive scaffold and assisting in vascularization and bone remodelling.[31] Therefore, the surfaces listed above were chosen because they are regarded as the gold standard and have a proven track record of promoting osseointegration.

The field emission scanning electron microscope (FESEM) with energy dispersive X-ray spectrometer (EDS)

(Thermo Scientific™ Quattro ESEM, USA) was used to quantitatively analyse the micro and nano topography and chemical composition of the Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® implants. Then, using a contact angle meter and the sessile drop technique, the water and solvent contact angles were determined to determine the surface wettability of the three commercially available implants.[24] The current study utilised the sessile drop approach for surface wettability measurement due to its speed and relative simplicity. Furthermore, heterogeneity can be ascertained by depositing many droplets in different positions on the sample; the reproducibility of certain contact angle values will also represent the heterogeneity of the energy characteristics of the surface. The Kitazaki-Hata hypothesis was then used to determine surface-free energy.[25] In contrast to Zimmer® Trabecular MetalTM, which was hydrophobic with lower wettability and surface energy, Straumann® BLX Roxolid® and Laser-Lok® surfaces were found to have higher surface wettability and energy, indicating a more hydrophilic nature.

Given the significance of fibrin clot formation during the osseointegration process to support cell migration and differentiation, platelet concentrates may offer all the components required to support these processes, including leukocytes, growth factors, fibrin mesh, platelets, and critical proteins like vitronectin and fibronectin.[18] Immediate or early implant loading may be possible with a shorter implant osseointegration period. Peri-implant bone repair may be aided by the local administration of growth factors and proteins via C-PRF preparations for biomimetic functionalisation of the implant surface. A higher concentration of platelets and leukocytes is produced by concentrated platelet-rich fibrin (C-PRF) for use in liquid injection. It is believed to generate significantly greater amounts of several growth factors, including PDGF, TGF-β1, VEGF, EGF, and IGF, in comparison to other types of PRF, which in turn promotes angiogenesis, cell migration, and differentiation. Therefore, C-PRF in conjunction with a nanotextured surface may have an osteopromotive effect during peri-implant bone healing in order to accomplish an autologous biomimetic functionalisation of implant surfaces and enhance the osseointegration process. This is especially true for patients with altered bone metabolism and less predictable osseointegration, such as those receiving bisphosphonate therapy, radiation therapy, smoking, or immediate implant placement.[17]

As a result, the relationship between C-PRF and various dental implant surfaces was assessed. To avoid potential bias from differences in blood components, the specimens for this study were taken from a single healthy person, and the platelet index was measured at baseline. For three minutes, the gathered samples were centrifuged at about 700 RCF.[16] A sterile syringe was then used to aspirate C-PRF, which was then promptly transferred to Eppendorf tubes. For 60 minutes at room temperature, implants made of Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® were fully submerged in C-PRF. After that, the implants were carefully taken out, repaired, and examined with a FESEM.[8] In the current study, FESEM was utilised because of its high-resolution capability, which may enable evaluation of organisation from the macromolecular level upwards, and because the low electron beam energies used for imaging lessen the possibility of beam-induced specimen damage, improving the preservation of delicate structures.

One important factor influencing the outcomes was the micro/nano topography of the implant surfaces. Higher surface energy on surfaces with more nanoscale structure enhances blood wettability and, consequently, the diffusion and attachment of fibrin and matrix proteins. By encouraging cell division and proliferation, nanopatterning may alter the behaviour of cells. The surfaces of Laser-Lok® and Straumann® BLX Roxolid® displayed a consistent and thick layer of fibrin. This is explained by the implant surfaces' hydrophilic properties. On the other hand, the Zimmer® Trabecular MetalTM implant surface had sizable areas devoid of fibrin covering, which may have been caused by the hydrophobic surface. The fibrin mesh on the Straumann® BLX Roxolid® and Laser-Lok® surfaces was thicker and denser than that on the Zimmer® Trabecular MetalTM implant surface, which showed a thinner fibrin layer with fewer fibrin fibres. Additionally, in comparison to the Zimmer® Trabecular MetalTM and Laser-Lok® surfaces, the Straumann® BLX Roxolid® surface displayed a greater number of cells trapped within the fibrin mesh.

In order to understand the orientation and interaction of fibrin fibres at the level of surface modification, cross sections of the Straumann® BLX Roxolid® and Zimmer® Trabecular MetalTM implants were taken at the level of the implant body, while cross sections of the Laser-Lok® implant were taken at the collar region. In contrast to the Laser-Lok® and Zimmer® Trabecular MetalTM surfaces, where the fibre orientation was more perpendicular to the surface, the Straumann® BLX Roxolid® surface had fibres orientated parallel to the implant surface. The perpendicular orientation of the fibres may be due to the elemental tantalum surface of Zimmer® Trabecular MetalTM, which is chemically stable and biologically inert, as well as the nanotextured surface with enhanced and uniform pore size. Regarding the Laser-Lok®, the perpendicular orientation of fibrin fibres might have been the consequence of the microchannels that increased the surface area.

Since this is the first study that compares the interactions of the implant surfaces of Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser Lok® with C-PRF, these results cannot be compared with those of other studies. However, Catherine X. Andrade et al. 8 assessed the interaction between liquid fibrinogen and five distinct dental implant surfaces (OsseospeedTM, TiUniteTM, SLActive®, Ossean®, and Plenum®) in an in vitro investigation. All implant surfaces developed a stable fibrin mesh when exposed to liquid fibrinogen, which was consistent with the current study's findings despite a

variety of macroscopic and microscopic variations in the uniformity, thickness, number, and orientation of the fibrin fibres.[8]

The present study's results demonstrated how various implant surface characteristics, including topography, wettability, and coatings, can alter the way the implant surface interacts with the fibrin mesh. Accordingly, some implant surfaces may be more suitable for biomimetic functionalisation using platelet concentrates.

The observational nature of the data and the small number of implant surfaces examined are limitations of the current study, despite the fact that it assessed implants with unique nano surfaces, such as SLActive surface, laser microtextured surface (LMS), and trabecular implants, which demonstrated promising clinical outcomes in fostering osseointegration and soft tissue attachment. Additional research is necessary to assess how biomimetic functionalisation with C-PRF promotes osseointegration and the therapeutic consequences of these findings on the longevity and success of dental implants.

Conclusions

Within the limitations of the present study, the following conclusions can be drawn, the Zimmer® Trabecular Metal™, Laser-Lok® implant surfaces exhibited perpendicular orientation of fibrin fibres, though there were no cells present. On the other hand, the Straumann® BLX Roxolid® surface featured an increased number of cells with a parallel fibrin orientation which is an important finding that could be detrimental for osseointegration in clinical scenarios. In the future, a new hybrid surface should be developed with laser lok microchannel at the collar region for enhanced tissue adaptation and an effective biologic seal, nano-textured porous body structure similar to the cancellous bone that supports bone integration, remodelling, and vascularization and with an SLActive surface to improve hydrophilicity and cellular infiltration to facilitate optimal osseointegration and improve long-term treatment outcomes.

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Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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