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A comparative surface analysis of zirconia, Titanium and titanium-zirconium dental implants

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Topic: Basic research

Abstract

INTRODUCTION: the osseointegration of the implant depends upon the surface itself. In addition to the biofunctional aspects, aesthetic considerations began to gain relevance, and thus came the ceramic implants (eg zirconia) as an alternative to titanium implants. PURPOSE: characterize the surface of titanium implants, titanium-zirconium and zirconia, investigating the relationship between characteristics such as chemical composition and crystallographic, wettability and roughness in the known results of osseointegration. MATERIALS AND METHODS: a Straumann Standard Plus SLA® implant tissue level of titanium, two implants Straumann SLA® Roxolid® Loxim™ titanium and zirconium (a bone level and a tissue level), two Straumann zirconia implants Pure Ceramic ZLA™. The tests are: X-ray diffraction; optical profilometry; measurement of contact angle; scanning electron microscopy with energy dispersive X-ray spectrometry and artificial aging. RESULTS: In the X-ray diffraction analysis all implants have confirmed the existence of the base elements; the zirconia implant obtained lower roughness values on the rough area; the monoclinic fraction of zirconium oxide was superior to the tetragonal fraction before and after artificial aging; the zirconia implant on scanning electron microscopy showed fine and rounded grains. CONCLUSION: Association between the topographical micrometer aspect with the nanometer one; it was found that the roughness of the zirconia implant is lower than the titanium and the titanium-zirconium implants, the last one have larger surface roughness values; after aging, it was found that the proportion of zirconium oxide in the monoclinic phase increased and remained above the proportion of tetragonal phase. KEY-WORDS: ceramic, dental implant, zirconia, titanium, surface characterization.

Background and Aim

The use of zirconia implants could be a viable alternative to the metal alloys to fill in the aesthetic and functional parameters especially when there is a thin tissue biotype and it has a reduced affinity for bacterial plaque lowering the risk of inflammatory changes in the surrounding soft tissues.

Success or failure of dental implants is directly related to the degree of integration of the implant material by surrounding soft and hard tissue. This ability depends, among other factors, on the surface topography, in particular the roughness which affects the bone-implant response.

Roughness is increased and chemical composition enhanced on the surface of zirconia implants with microgrooves which improve the cell-surface interactions and stimulate cell activity. In general, a positive correlation is found between an increasing Sa value and stronger bone or tissue integration at least up to a certain level of roughness.

The purpose of this study is characterizing the surface of zirconia implants and compare with titanium and titanium-zirconium implants, investigating the roughness of their surfaces. Another purpose is to verify if the micrometric and nanometric topography of the zirconia are similar to the titanium and titanium-zirconium implants. This characterization is essential to establish the importance of surface roughness of the implants and their relationship in osseointegration.

Methods and Materials

A Straumann Standard Plus SLA® tissue level implant of titanium (diameter: 4.1mm, length: 8mm); two implants Straumann SLA® Roxolid® Loxim™ of titanium and zirconium: a bone level (diameter: 3.3mm, length: 8mm) and a tissue level (diameter: 4.1mm, length: 8mm). Two Straumann implants Pure Ceramic ZLA™ of zirconia (diameter: 4.1mm, length: 8mm, AH: 4mm). The tests are: x-ray diffraction; optical profilometry; contact angle; scanning electron microscopy with energy dispersive X-ray spectrometry; artificial aging.

The artificial aging was made following the recommendations of ISO 13356.

Results

Contact angle measurements shows both SLA® and ZLA™ surfaces are hydrophobic (Figure 1, Table 1). The zirconia implant show a lower value of Sa in the rough area (Figure 2-3, Table 2). Zirconia implant has a different topography than titanium and Ti-Zr implants, which has a crystallographic aspect with compact grains (Figure 4-5). The X-ray diffraction results of zirconia implants before and after aging shows the presence of zirconium oxide in the tetragonal (the major part) and monoclinic phase (Figure 8-9). The energy dispersive X-ray spectroscopy analysis show the presence of aluminium on the surface of titanium-zirconium implant (Figure 6-7). After the artificial aging of the zirconia implant, the presence of calcium carbonate was shown on EDS (Figure 10-11).

Notice that carbon was deposited on zirconia implant for a better conduction of electrons during the test.

The authors declare no conflict of interest

Figure 1: SBF drop on implant surface for contact angle measurements.

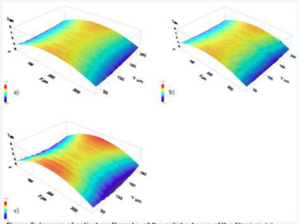

Figure 2: Images of optical profilometry of the polished area of the titanium (a), titanium-zirconium (b) and zirconia (c) implants.

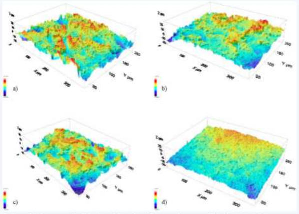

Figure 3: Images of optical profilometry of the rough area of the titanium (a), titanium-zirconium tissue level (b), titanium-zirconium bone level (c) and zirconia (c) implants.

Zirconia	Polished	Rough
Sdr (%)	0,572	38,548
Contact angle (°)	90,944	109,766
Titanium	Polished	Rough
Sdr (%)	0,213	185,840
Contact angle (°)	104,994	99,114
Titanium-zirconium tissue level	Polished	Rough
Sdr (%)	0,182	149,237
Contact angle (°)	94,607	93,8101
Titanium-zirconium bone level	Polished	Rough
Sdr (%)	...	150,800
Contact angle (°)	...	93,291

Table 1: Values of contact angle measurements.

Zirconia	Polished	Coronary	Apical	Top	Valley
Sdr (%)	0,572	65,136	38,548		
Sa (μm) 52.84x52.84 μm^2	0,2423	1,630	1,1828	1,389	1,426
Titanium	Polished	Coronary	Apical	Top	Valley
Sdr (%)	0,213	142,410	185,840		
Sa (μm) 52.84x52.84 μm^2	0,127	2,825	2,649	2,822	2,862
Titanium-zirconium tissue level	Polished	Coronary	Apical	Top	Valley
Sdr (%)	0,182	164,608	149,237		
Sa (μm) 52.84x52.84 μm^2	0,146	3,607	2,871	4,627	3,899
Titanium-zirconium bone level	Polished	Coronary	Apical	Top	Valley
Sdr (%)	não tem	174,500	150,800		
Sa (μm) 52.84x52.84 μm^2	não tem	3,664	4,147	3,841	3,331

Table 2: Values of Sa measurements.

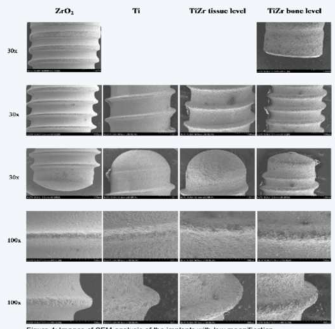

Figure 4: Images of SEM analysis of the implants with low magnification.

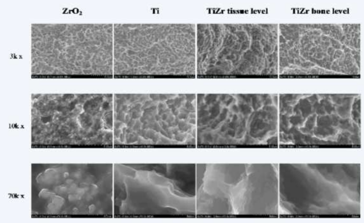

Figure 5: Images of SEM analysis of the implants with high magnification.

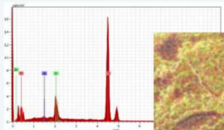

Figure 6: Results of EDS of titanium-zirconium tissue level implant.

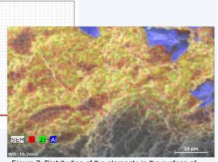

Figure 7: Distribution of the elements in the surface of titanium-zirconium tissue level implant.

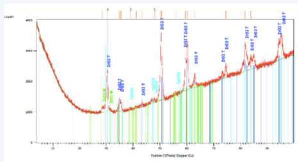

Figure 8: XRD of zirconia implant 2 before aging. The percentage of the elements are: zirconium oxide on tetragonal phase 28%; zirconium oxide on monoclinic phase 30% and calcium carbonate 42%.

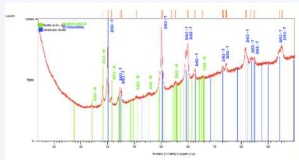

Figure 9: XRD of zirconia implant 2 after aging. The percentage of the elements are: zirconium oxide on tetragonal phase 43%; zirconium oxide on monoclinic phase 57%.

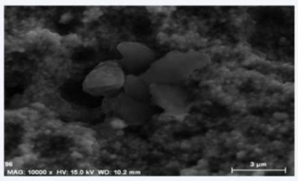

Figure 10: Image of SEM during the EDS test after the aging of the zirconia implant 2 showing a different agglomerate of higher particles.

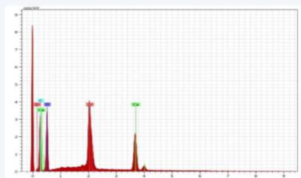

Figure 11: EDS results of the anterior image of SEM, indicating the presence of calcium carbonate, zirconium and oxygen on zirconia implant 2 after aging.

Conclusions

The roughness of the rough area of titanium-zirconium implants is higher than titanium and zirconia. On the other hand, the roughness of the zirconia implant is lower and has a different topography than the titanium and titanium zirconium implants. The compact aspect of the zirconia grains prove the difficulty of stress propagation on its surface. Before and after the artificial aging, the percentage of zirconium oxide in monoclinic phase was higher than the tetragonal phase, which can be suspected that surface treatments can change the phase of zirconium oxide from T-M.

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