In vitro biofilm formation on commercially available machined and micro-roughened titanium and zirconia implant surfaces

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Background: It has been shown that biofilm formation and subsequent plaque accumulation on implant surfaces can induce peri-implant infections and that besides surface roughness and surface free energy, the type of biomaterial can also influence the bacterial adhesion and colonization on implant surfaces. In recent years, zirconia has become an alternative to titanium for the fabrication of dental implants and it has been hypothesized that zirconia might have a reduced bacterial adhesion compared to titanium; however, results from experimental studies are rather controversial.

Aim/Hypothesis: The aim of the present experimental study was to investigate and compare biofilm formation on commercially available machined and micro-roughened zirconia and titanium implant surfaces using an in vitro 3-species biofilm and human plaque samples.

Material and methods: Experimental disks made of titanium (Ti-M, Ti-SLA) or zirconia (ZrO2-M, ZrO2-ZLA) with a machined or a sandblasted and acid-etched surface topography, respectively, were produced. Initially, disks were coated with an in vitro 3-species biofilm, consisting of Streptococcus sanguinis, Porphyromonas gingivalis and Fusobacterium nucleatum, or with human plaque samples that were collected from 4 patients within the course of a regular oral hygiene recall. Following to that, the disks were incubated in an anaerobic flow chamber. Finally, after 72 h of incubation, structure, amount, thickness and metabolism of the formed biofilms were evaluated by using scanning electron microscopy (SEM), safranin staining, 4',6-diamidino-2-phenylindol (DAPI) staining combined with confocal laser scanning microscopy (CLSM) and isothermal microcalorimetry (IMC). Each microbiological experiment was conducted 3 times (n = 3) on each type of titanium and zirconia disks.

Results: The 3-species biofilm evaluation showed structured and organized biofilms only on Ti-SLA, whereas ZrO2-ZLA, ZrO2-M and Ti-M showed single aggregates of bacteria. Additionally, zirconia showed statistically significantly reduced 3-species biofilm thickness compared to titanium [ZrO2-M: 8.41 µm; ZrO2-ZLA: 17.47 µm; Ti-M: 13.12 µm; Ti-SLA: 21.97 µm]; however, no differences were found with regard to 3-species-biofilm mass and metabolism. Human plaque analysis showed optical density values of 0.06 and 0.08 for ZrO2-M and ZrO2-ZLA, and values of 0.1 and 0.13 for Ti-M and Ti-SLA, respectively, indicating statistically significantly reduced human biofilm mass on zirconia compared to titanium. Additionally, zirconia revealed statistically significantly reduced human plaque thickness [ZrO2-M: 9.04 µm; ZrO2-ZLA: 13.83 µm; Ti-M: 13.42 µm; Ti-SLA: 21.3 µm] but a similar human plaque metabolism compared to titanium.

Conclusions and clinical implications: After 72 h of incubation, 3-species biofilm evaluation only showed statistically significant differences between zirconia and titanium with regard to biofilm thickness. However, two out of three quantitative microbiological techniques showed statistically significantly reduced human plaque biofilm formation on zirconia compared to titanium implant surfaces. Thus, it might be suggested that zirconia surfaces might have a reduced disposition for peri-implant plaque formation.