DENTAL MATERIALS 32 (2016) 1524–1535

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Adhesion of living cells to abutment materials, dentin, and adhesive luting cement with different surface qualities

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ARTICLE INFO

Article history:
Received 14 May 2016
Received in revised form
10 August 2016
Accepted 3 September 2016

Keywords:
Titanium
Zirconium dioxide
Lithium disilicate
Ceramic
Surface treatment
Physico-chemical properties
Cell adhesion
Dentin
Resin cement
Single-cell force spectroscopy

ABSTRACT

Objective. We tested the adhesion properties of living gingival fibroblasts on three different implant abutment materials, adhesive resin used to bond bi-partite abutments, and human dentin.

Methods. Discs of lithium disilicate (LS), zirconium dioxide (Zr), adhesive resin cement (AR), titanium (Ti), and human dentin (HD) were fabricated with three different levels of surface roughness (rough, machined, and polished). Ra and Rz, water contact angle, and cell detachment forces were measured. Cell detachment force was measured for single cells using single-cell force spectroscopy. Data were statistically analyzed using parametric tests (ANOVA, MANOVA, Bonferroni post-hoc tests).

Results. Surface roughness significantly influenced the water contact angle for all materials ($P \leq 0.05$). Overall, HD showed the lowest contact angle, followed by LS, Ti, Zr, and AR ($P \leq 0.05$). Comparison of cell detachment forces between materials with rough and machined surfaces revealed no significant differences ($P > 0.05$), with the exception of Zr compared to HD with rough surfaces ($P = 0.006$). For polished surfaces, HD showed the highest detachment force ($P \leq 0.0001$), followed by Ti, AR, and Zr, which did not significantly differ from each other ($P > 0.05$) and LS; Ti/AR was significantly different from LS ($P \leq 0.05$). Except for HD, where polished surfaces exhibited the highest cell detachment force ($P \leq 0.002$), most machined surfaces showed higher cell detachment forces than polished or rough surfaces.

Significance. Implant abutments should ideally be provided with a machined like surface roughness for best cell adhesion.

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http://dx.doi.org/10.1016/j.dental.2016.09.006

1. Introduction

Dental implant abutments should have the following characteristics: (1) ensure stability of both, soft and hard tissues [1–3]; (2) cause no, or only limited, wear of the implant/abutment connection [4–7]; (3) exhibit low plaque accumulation rates [8–10]; (4) be biocompatible (no allergic reactions, no stimulation of the immune system [11–13]; and (5) should be aesthetically acceptable (no metal discolouration of the gingiva) [14,15]. Commonly used materials providing most, but not all, of these properties include: CP4 pure titanium Grade 1 abutments [1,16], zirconium dioxide ceramic abutments [1,16], and recently introduced lithium disilicate ceramic abutments [17].

Marginal bone loss of approximately 0.6 mm appears to be inevitable because of surgical trauma after implant placement [18,19]. Further bone loss should be avoided to prevent aesthetical problems [20]. The established peri-implant connective tissue resembles scar tissue in composition, fibre orientation, and vasculature [21]. The connective tissue forms a ring around the abutment and rests on the platform-switched implant shoulders. One of the main functions of the peri-implant soft tissue is to seal the marginal bone and protect the host from bacterial penetration [2,10,22].

Surface properties modify cell behaviour [23,24], and surface alterations can achieve specific cell responses [24,25]. Although many parameters are involved, surface roughness and wettability are two important factors for cell adhesion and proliferation [24,26].

Previous studies have improved the implant seal using different cleaning procedures [27–29] or surface alterations [24,30–33]. The abutment materials evaluated in most of these studies were titanium abutments [33–35], with one study using zirconium dioxide [29] and another using lithium disilicate [24]. It has generally been established that a rough titanium surface increases cell growth/migration and expression of proteins in the extracellular matrix [29,36,37]. Although both, osseous- and soft tissue healing around dental implants are critical for clinical success, there is limited information available regarding the effect of different implant surfaces on cell adhesion and integrin expression in soft tissues [37]. Most studies have relied on percentage-wise anatomic descriptions of cell proportions [35,36] and cell growth analysis [24]. Some studies have investigated the biochemical and physiological details of cell alterations and adhesion properties [37]. In recent years, single-cell force spectroscopy has become a valuable tool for investigating the adhesion properties of cells [38], particularly because it enables comparison of adhesion on different surfaces using the same cell [39,40].

The null-hypotheses to be tested were:

Short-term cell adhesion and water contact angle measurements using single-cell force spectroscopy are not influenced by the use of three different implant abutment materials, adhesive resin and dentin. Equally, different surface roughnesses have no significant influence on short-term cell adhesion and water contact angle measurements.

2. Materials and methods

2.1. Materials used

The main materials used in this study are shown in Table 1. Overall, five materials with three different surface characteristics were tested: lithium disilicate (LS), zirconium dioxide (Zr), adhesive resin cement (AR), titanium (Ti), and human dentin (HD). Specimens of LS (IPS e.max CAD MO3, Camlog Dedicam, Wimsheim, Germany) composed of SiO_2 (57–80%; all shown in weight%), Li_2O (11–19%), KO_2 (0–13%), P_2O_5 (0–11%), ZrO_2 (0–8%), ZnO (0–8%), and others oxides and pigments (around 7%). Samples of Zr (Zirlux FC2 U5, Camlog Dedicam) composed of ZrO_2 (>91%), Y_2O_3 (5.3%), Al_2O_3 (<0.15), and HfO_2 (<3%). Specimens of AR (Multilink Hybrid Abutment, Ivoclar Vivadent, Schaan, Liechtenstein) composed of (Base) Yb_3F_3 (10–25%), ethoxylated bisphenol-a-dimethacrylate (10–25%), Bis-GMA (10–25%), 2-hydroxyethyl-methacrylate (3–10%), and 2-dimethylaminoethylmethacrylate (0.3–1%) and (Catalyst) Yb_3F_3 (10–25%), ethoxylated bisphenol-a-dimethacrylate (10–25%), urethane dimethacrylate (3–10%), 2-hydroxyethyl-methacrylate (3–10%), and dibenzoylperoxid (1–2.5%). Specimens of Ti (Ti-6Al-4V ELI (ASTM F 136), Camlog Dedicam) consisted of Al (5.5–6.5%), V (3.5–4.5%), and C, Fe, O, N, and H (all <0.13%) with the remaining amount comprised of titanium.

2.2. Specimen preparation

LS, Zr, and Ti specimens were manufactured by CAD/CAM (Camlog Dedicam). The dimensions of the specimens were 10 mm (depth) × 10 mm (width) × 1 mm (height), with the exception of HD, which naturally exhibits minor irregularities in depth and width. The ceramics were used in the sintered stage. Overall, 24 specimens per group were prepared.

AR specimens were produced by initially taking impressions of Ti specimens (Gammasil Perfect TEC A85, Müller-Omicron, Cologne, Germany). Next, AR was mixed according to the manufacturer's instructions, placed into the silicone mould, and covered with glycerine gel (Liquid Strip, Ivoclar Vivadent, Schaan, Liechtenstein). After 10 min, the AR block

Table 1 – Main materials used in this study. Data listed below are provided by the manufacturers.

Proprietary material	Lot no.	Type	Manufacturer
Multilink Hybrid Abutment	T15412	Adhesive resin	Ivoclar Vivadent, Schaan, Liechtenstein
Titanium Ti-6Al-4V ELI	D0065.6305	Titanium alloy	Camlog Dedicam, Wimsheim, Germany
Lithium disilicate	D0065.6408	IPS e.max CAD MO3	Camlog Dedicam
Zirconium dioxide	D0065.6347 C2242.4308	Zirlux FC2 U5	Camlog Dedicam
Human gingiva fibroblast cells	305110-212	Fibroblast cells	Cell line services Eppelheim, Germany