

Response of soft tissue to different abutment materials with different surface topographies: a review of the literature

Feras Al Rezk, DDS, MSc, DIOCI, FAGD ■ Georgia Trimpou, DMD, Dr med dent
Hans-Christoph Lauer, DMD, PhD, Dr med dent ■ Paul Weigl, Dr med dent ■ Nadine Krockow, Dr med dent

Soft tissue integration in the transmucosal zone of dental abutments supports the peri-implant tissues, improves esthetics, ensures soft tissue seal against microorganisms, and preserves crestal bone level. The aim of this literature review was to define the most favorable surface topography and macrodesign of the transmucosal zone of abutments to achieve optimal soft tissue seal. An electronic search of the PubMed/MEDLINE database was performed, seeking relevant English-language articles published between January 1, 2003, and October 11, 2014. The key terms *implant abutment*, *surface topography*, and *soft tissue seal* were used both singly and jointly with “AND” in this search. Additionally, a manual search was performed. Articles that did not distinguish between abutment and implant surfaces, investigated only 1-piece dental implants, or were systematic reviews were excluded, although 4 systematic reviews were studied to obtain background information. Out of a preliminary pool of 206 articles, 12 relevant articles were identified for final evaluation in addition to the 4 systematic reviews. These included 3 human studies, 3 animal studies, and 6 in vitro studies. The human histologic studies showed evidence of perpendicular insertion of human gingival fibroblasts into the treated abutment surface. Laser-ablated, hydrophilic, and oxidized titanium surfaces resulted in this type of attachment. Epithelial cells seem to slightly favor zirconia and polished titanium surfaces. Due to heterogeneity in the study designs, statistical methods, and reported results, meta-analysis of the data was not possible. Improvements in the surface topography and macrodesign of dental abutments might improve biocompatibility and adherence to soft tissue; however, manipulation of soft tissue and second-stage surgery could negate any advantages of the improved surfaces.

Received: March 29, 2017

Accepted: May 10, 2017

Published with permission of the Academy of General Dentistry. © Copyright 2018 by the Academy of General Dentistry. All rights reserved. For printed and electronic reprints of this article for distribution, please contact jkaletka@mossbergco.com.

**GENERAL DENTISTRY
SELF-INSTRUCTION**



Exercise No. 414, p. 26

Subject code: Implants (690)

Soft tissue integration in the transmucosal zone of dental abutments is an essential functional and biologic parameter for supporting the peri-implant tissues, improving esthetics, ensuring soft tissue seal against microorganisms, and preserving crestal bone level, ultimately increasing the longevity of the restoration. Healthy integration of the soft tissues around the prosthetic components of a dental implant offers a protective zone that prevents epithelial downgrowth and stabilizes and protects the surrounding bone from harmful biologic and mechanical factors. The physical gap between the abutment-crown complex and the soft tissue surrounding the implant restoration is a pathway for the invasion of microorganisms to the dental implant surface, which may lead to bone loss and peri-implantitis. A proper soft tissue seal can act as a clinical strategy to prevent microbial invasion of the dental implant surface.

Tissue healing around the implants can also be influenced by biomechanical factors such as the implant-abutment stability, the shape and design of the components, and the microtopography of the implant surface.^{1,2} Polished titanium or zirconia components are conventionally used in the transgingival part of the dental implant abutment as connective elements to prosthetic suprastructures. However, these biocompatible materials cannot always offer support for a tight peri-implant soft tissue seal, eventually leading to bacterial invasion.

The materials used for prosthetic components in implantology must meet high esthetic demands and reduce the risk for plaque accumulation. Myshin & Wiens examined soft tissue healing in both partially and completely edentulous dental implant patients.³ However, their study did not address the soft tissue seal around the dental implants. Iglhaut et al, in a comprehensive review of the literature, investigated epithelial downgrowth in response to different abutment macrodesigns, such as concave, platform-switching, and microgrooved abutments.⁴ That study addressed the bone loss related to the interface quality between dental abutment and soft tissue. However, the authors did not search for the ideal surface topography that may result in optimal soft tissue seal.

Linkevicius & Apse, in a systematic review of research on the peri-implant tissue stability associated with different abutment materials, could not find any significant differences in the currently available materials and the resulting tissue stability.⁵ In vitro and in vivo research has shown that dental abutment materials with different characteristics have an influence on the health of the soft tissue and the ability of the abutments to preserve crestal bone around dental implants.⁵ According to Linkevicius & Apse, however, studies comparing gold to

Table 1. Parameters of soft tissue around natural teeth and titanium dental abutments.^{3,4,7-13}

Parameter	Natural tooth	Dental implant
Mean soft tissue height ⁷	2.73 mm	3.0-3.5 mm
Mean epithelial width ⁷	2.05 mm	2.40 mm
Mean connective tissue width ⁹	1.12 mm	1.66 mm
Type of epithelial attachment ¹⁰	Hemidesmosomes	Partially hemidesmosomes
Connective tissue attachment ¹¹	Perpendicular to the cementum	Layer of proteoglycans, 20.0 µm thick
Collagen fiber insertion ¹²	Perpendicular to the tooth surface	Parallel to the implant surface, as with scar tissue
Ratio of collagen fibers to fibroblasts ¹³	60% collagen fibers to 5%-15% fibroblasts	85% collagen fibers to 1%-3% fibroblasts
Source of vascularity ¹³	Supraperiosteal blood vessels and vascular plexus of the periodontal ligament	Peri-implant soft tissue from supraperiosteal blood vessels

titanium have shown no significant differences in soft tissue and bone health around the 2 materials.⁵ Histologic studies comparing aluminum oxide to titanium also show similar results for tissue and crestal bone levels. Although soft tissue slightly favors zirconium oxide dental abutments compared with titanium, no statistically significant differences have been found.⁵

It is important to consider how the interaction of an inorganic material, such as a titanium abutment, and soft tissue differs from the interaction around a natural tooth. The embedded part of the primary group of fibers that runs between bone and cementum (known as *Sharpey fibers*) creates a biologic bond that makes the cementum an essential functional part of the periodontal apparatus.^{6,7} It would be ideal to pursue a dynamic, functional surface similar to that found in nature to cover dental abutment and implants.

Different factors influencing the transmucosal seal have been investigated.^{3,4,7-13} Among the factors that have been considered, the presence of keratinized mucosa has the most positive effect on the soft tissue architecture and the ability of the tissue to resist stress of mastication, trauma, or recession. The design of dental abutment, the type of connection of the abutment, and platform switching between dental abutment and dental implant seem to positively influence hard tissue stability and consequently soft tissue health and peri-implant esthetics.

Soft tissue attachment around dental abutments has some similarities to soft tissue attachment around natural teeth, including mucosa, junctional epithelium, and connective tissue attachments that are similar in biologic width. However, there are also some important differences between the connective tissue attachments around implants and teeth (Table 1).^{3,4,7-13} The connective tissue has a similar free gingival structure of keratinized epithelium around both implants and natural teeth, but the collagen fibers of the connective tissue around dental implants run parallel to the abutment surface.⁷ In addition, the peri-implant connective tissue shows poor vascularity and appears more like scar tissue.

Different types of dental implant surface topography (machined, acid-etched, or sandblasted) did not influence soft tissue healing.³ The sulcus around the implant appears to be made from nonkeratinized epithelium, and a zone of circular fibers

constitutes the connective tissue zone.³ No mechanical or chemical attachment of the fibroblasts to the abutment surface has been found. In implants, that attachment is replaced by a proteoglycan layer that basically consists of heavily glycosylated proteins.

The composition of connective tissue around natural teeth and dental implants also differs.⁴ The connective tissue zone established around natural teeth is composed of 60% collagen fibers and up to 15% fibroblasts. In contrast, the connective tissue around dental implants comprises 85% collagen fibers and only up to 3% fibroblasts.^{4,13}

Some studies show that bone-level implants have more epithelial downgrowth than soft tissue-level implants.⁴ The dental abutment interface influences crestal bone level; it has been concluded that this result is a direct effect of the microgap.⁴ Infiltration of inflammatory cells found on bone-level dental implants may be caused by microorganisms in the oral cavity. There is also evidence that microleakage of endotoxins occurs at conical abutment-implant connections.⁴ Gram-negative microorganisms may cause crestal bone resorption by activating osteoclasts. Lipopolysaccharide-mediated cytokines may penetrate even small gaps in a conical connection, which will contribute to the destruction of crestal bone.

The connective tissue seal and bone surrounding dental implants are also influenced by oral biofilms. A biofilm is a community of microbial cells embedded within an extracellular matrix produced by the microorganisms themselves and attached to a substratum.¹⁴ Dental plaque is constituted by complex communities of biofilms. Microbes in dental plaque are important factors in the formation of mucositis and peri-implantitis. Factors such as the surface topography, surface energy, and surface chemical characteristics of dental abutments as well as the prosthetic interface with dental implants may influence the formation and development of biofilms and eventually peri-implant diseases.¹⁵ The same factors that influence biofilm formation may influence the adhesion and proliferation of gingival epithelial cells and fibroblasts.

Another factor influencing soft tissue seal around implants is the crestal bone loss that occurs after second-stage uncovering of implants. So-called bone dieback, which is 1.0-1.5 mm of bone loss to the first thread of the dental implant, occurs

within the first year of functional implant loading.¹⁶ The dieback phenomenon seems to continue with an annual average of 0.1 mm of bone loss for the rest of the functional life of an implant and has been discussed in correlation to the abutment-implant junction.⁵ The usage of an internal, long, conical connection has been discussed as a means of reducing crestal bone loss. In addition, platform switching (horizontal offset) seems to have a positive effect on bone at the implant-restoration complex.⁴ These methods have reduced but not eliminated the peri-implant bone dieback phenomenon.

The objective of the present study was to review the literature on the surfaces, chemistry, materials, and topography of dental implant abutments in relation to soft tissue seal and to determine specific topographic characteristics of abutment surfaces that could lead to better sealing and superior long-term stability of the peri-implant tissues. A better understanding of the relationship between soft tissue and dental abutment surface could help clinicians in their selection of abutment materials and surfaces. It was hypothesized that abutments with a microtopography similar to that of tooth enamel will achieve better soft tissue seal, thereby preventing microbial invasion, preserving crestal bone, and ultimately leading to a better success rate.

Materials and methods

Search strategy

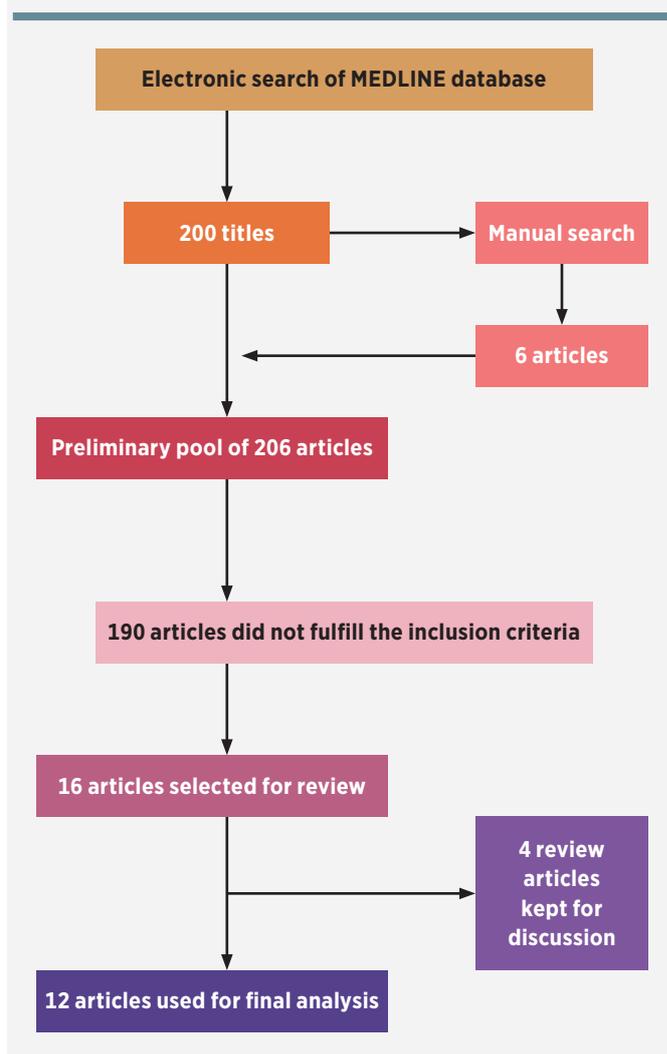
An electronic search through the PubMed/MEDLINE database for relevant articles published January 1, 2003, through October 11, 2014, was performed. All types of studies investigating the dental abutment surface material and topography as well as the soft tissue response were included. After the electronic search, a manual search was carried out to include laser-ablated dental abutment surfaces.

The key terms *implant abutment*, *surface topography*, and *soft tissue seal* were used both alone and as combined search terms. The search terms were grouped to the subjects (implant abutment, surface topography, soft tissue seal) and linked with "AND." After the abstracts of the preliminary pool were read, only the articles that clearly discussed soft tissue relationships with the dental abutment surface were selected for a full-text article review.

The inclusion criteria were articles written in the English language, published January 1, 2003, through October 11, 2014. The exclusion criteria were articles that did not distinguish between abutment and implant surfaces, articles that investigated only 1-piece dental implants without examining the transmucosal surface and its relationship to soft tissue seal, and systematic reviews. Although excluded from the analysis, 4 systematic reviews were studied to obtain a better understanding of the topic.

The full-text article pool was divided based on the type of study—human, animal, and in vitro—because different kinds of studies might improve the overall perspective and broaden the sources of evidence collected. While in vivo studies might represent the ideal environment to investigate soft tissue responses to dental abutment materials and surfaces, in vitro studies facilitate collection of evidence related to specific, isolated or multiple factors of the tissue response. The final pool of articles totaled 16: 4 review articles, 3 animal studies, 3 human studies, and 6 in vitro studies.

Chart. Selection of articles for review.



Data analysis

When the full-text articles were reviewed, it was clear that differences in the study designs, measurement parameters, and data collection made it impossible to perform statistical analysis on the resulting heterogenous data.

Results

After all abstracts and titles were screened—200 from the initial search and 6 from the manual search—16 articles were selected for the final analysis (Chart). Although 4 of 16 articles were systematic reviews and therefore were excluded from the evaluation, they were read to obtain background information. Finally, 12 full-text articles meeting all the defined inclusion criteria were evaluated.

Excluded studies

The 190 studies excluded from the analysis did not meet the inclusion criteria. More specifically, the excluded articles gave no information related specifically to the surface topography and characteristics of dental implant abutments.

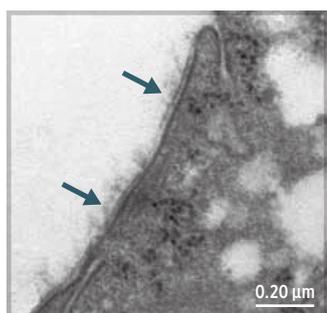


Fig 1. Transmission electron micrograph of the surface of a cell directly in contact with an implant. Note the presence of basal lamina and hemidesmosomes (arrows). (Reprinted from Schupbach & Glauser with permission from Elsevier.¹⁷)

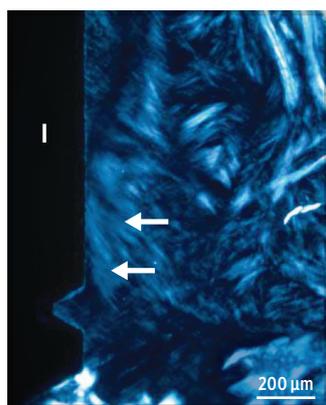


Fig 2. Longitudinal section through a human implant (I) with an oxidized surface showing functionally oriented collagen fibrils (arrows) in the apical portion of peri-implant connective tissue. (Reprinted from Schupbach & Glauser with permission from Elsevier.¹⁷)

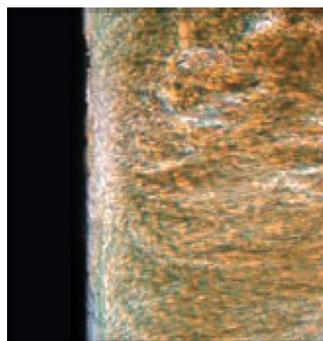


Fig 3. Modified hydrophilic titanium-zirconia surface showing improved adhesion and perpendicular collagen fibers (original magnification 200×). (Reprinted from Schwarz et al with permission from Wiley.¹⁸)

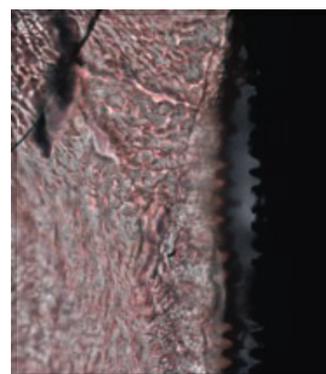


Fig 4. Improved seal around the healing abutment. (Reprinted from Iglhaut et al with permission from Wiley.²¹)

Included studies

All studies selected for the final pool of articles were prospective. Three human studies with a total of 32 patients, 2 canine studies with a total of 12 dogs, 1 subcutaneous model in vivo study in the rat, and 6 in vitro studies were included.¹⁷⁻²⁸

In the 3 prospective studies with human subjects, a total of 75 abutments had been utilized in 32 patients.¹⁷⁻¹⁹ There was a mean of 14.166 patients per study. The mean follow-up period was 1.66 months. The investigated histologic specimens showed evidence of perpendicular collagen fiber insertion into abutment surfaces made of hydrophilic-modified titanium or zirconium oxide.

Two of the animal studies involved a total of 12 dogs with a total of 72 abutments.^{20,21} The mean follow-up period was 2.375 months. Laser-ablated microgrooved abutments specimens showed full or partial histologic evidence of direct connective tissue attachment. However, when abutments were disconnected and reconnected, the direct connective tissue attachment was lost.

Discussion

Because this literature review was designed with broad inclusion criteria to include different types of studies, wide-ranging results related to different types of surfaces and materials were expected. Although this approach precluded statistical analysis of the data, it does not undermine the value of the evidence provided by the data itself.

Human studies

The 3 human studies included in the final review involved a total of 32 subjects with 75 dental abutments and a mean follow-up period of 1.66 months.¹⁷⁻¹⁹ One human study involved 12 titanium dioxide dental abutments, which had been divided into 3 types of surface: machined, acid-etched, and microporous oxidized.¹⁷

A second human study involved 18 dental abutments: 5 hydrophobic, machined titanium abutments; 6 chemically modified, hydrophilic, acid-etched titanium abutments; and 7 chemically modified, hydrophilic titanium-zirconium alloy abutments.¹⁸ The third human study involved 45 dental abutments divided into 5 groups to produce 5 different surface topographies: 1, the control group as received from manufacturer; 2, test abutments modified by a rotary process; 3, test abutments sandblasted with 25- μ m aluminum oxide particles; 4, test abutments sandblasted with 75- μ m aluminum oxide particles; and 5, test abutments sandblasted with 250- μ m aluminum oxide particles.¹⁹

These human studies found evidence that some special surface characteristics resulted in direct connective tissue attachment to the abutment surface. Schupbach & Glauser harvested experimental titanium mini implants 8 weeks after insertion.¹⁷ Histologic analysis revealed many similarities between soft tissues surrounding the specimens and those around natural teeth. The authors found evidence for a basal lamina and reported the existence of hemidesmosomes (Fig 1). The abutment portion of the 1-piece mini implant used in the study was designed to be placed at the soft tissue level. The specimens were grouped into 3 types of abutment surface: machined, acid-etched, and microporous oxidized. One of the significant findings of this study was that histologic evidence of collagen fibers that were perpendicularly oriented against the abutment surface was found only around specimens with an oxidized surface (Fig 2).¹⁷

Schwarz et al histologically compared tissue response to healing abutments in a multicenter, randomized controlled clinical trial of hydrophobic and hydrophilic surfaces.¹⁸ The biopsy specimens were harvested after 8 weeks of healing. The histomorphometric analyses as well as the microscopic observations showed that there was a gap between the mucosa and the machined abutments, while the modified hydrophilic abutments showed perpendicular collagen fibers (Fig 3).¹⁸

Table 2. Summary of the results of the reviewed in vitro studies.²³⁻²⁸

Study	Epithelial cells	Fibroblasts	Notes
Yang et al ²³		Proliferation and adhesion favored on treated rough surfaces	Ultraviolet irradiation of zirconia abutments to improve wettability
Kim et al ²⁴		Proliferation was similar between titanium nitrate and zirconia	
Nothdurft et al ²⁵	Proliferation of larger cells favored on polished surfaces, especially titanium	Proliferation favored on zirconia in general	
Moon et al ²⁶		Improvement with time to all specimens	Importance of no manipulation or disconnection
Baltriukienė et al ²⁷	Large cell proliferation favored on smooth surfaces	Adhesion favored on laser-ablated compared to sandblasted or polished surfaces; the greatest number of cells was found on polished titanium surfaces	Results contradict those of Yang et al ²³
Xing et al ²⁸		Cathodic polarization using organic acids improves growth of human gingival fibroblasts	

For their clinical study of 9 patients, Wennerberg et al replaced 5 original abutments with test abutments.¹⁹ Each of the 5 test abutments had a different surface roughness and remained mounted for 4 weeks. There were no statistically significant differences in the soft tissue response to the different abutments. The degrees of abutment surface roughness utilized were similar to those of commercially available dental abutments.¹⁹

Animal studies

The 2 canine studies involved a total of 12 dogs with 72 dental abutments. Each study used 6 foxhounds, and the mean follow-up was 2.375 months.

In the canine study by Nevins et al, machined abutments were compared with abutments that had microchannels distributed randomly on surfaces.²⁰ Scanning electron microscopic evaluation showed evidence of direct attachment of the connective tissue and perpendicular fibers on the laser-ablated abutment surfaces. The control groups, consisting of machined dental abutments, failed to develop such a desirable attachment and soft tissue seal.²⁰

Microchannel abutment surface topography was tested in another canine study by Iglhaut et al.²¹ This study also assessed the influence of disconnection and reconnection on the soft tissue healing response. The immunohistochemical analysis delivered evidence of connective tissue fibers perpendicular to partially or completely laser-ablated dental healing abutments, a finding that was not observed in the test group (Fig 4). The attachment was lost once the abutments had been disconnected.²¹

In another animal study, Kloss et al used a subcutaneous fibrous tissue model in the rat.²² Three groups of polished implant surfaces (titanium, titanium coated with hydrophobic nanocrystalline diamond, and titanium coated with hydrophilic nanocrystalline diamond) were placed in the subcutaneous connective tissue of rats. In all specimens removed

after 1 week, collagen fibers were developed parallel to the surfaces. However, hydrophilic surfaces exhibited an increased number of cells and a reduced inflammatory response. Among specimens removed after 4 weeks, hydrophilic surfaces still showed significantly greater numbers of cells and blood vessels than hydrophobic surfaces.

In vitro studies

Yang et al used ultraviolet irradiation to reduce water angle as a means to improve the wettability and hydrophilicity of zirconia and subsequently improve its biocompatibility with human gingival fibroblasts (Table 2).²³ Smooth and rough zirconia control groups were compared to test groups that consisted of smooth or rough zirconia discs treated with ultraviolet light for 24 hours. Water contact angle decreased significantly in both test groups. The authors concluded that ultraviolet light treatment improved human gingival fibroblast proliferation for both smooth and rough zirconia. However, the rough surface group favored longer cell adhesion and proliferation.²³

Kim et al investigated different dental abutments of different colors and materials: machined gray titanium, yellow titanium nitride-coated titanium alloy, pink anodic-oxidized titanium alloy, gray chrome-cobalt-molybdenum alloy, white composite resin, and white zirconia.²⁴ All surfaces had a surface roughness value of less than 0.5 μm ; however, the surface roughness value of zirconia was much less, 0.019 μm . The water contact angle was greater than 40 degrees for all the tested groups, varying from about 60 degrees (machined, nitride-coated, and anodic-oxidized titanium alloy as well as zirconia) to 90 degrees (chrome-cobalt-molybdenum alloy). Especially at day 7, the fibroblast proliferation around zirconia and nitride-coated specimens was the greatest. Consequently, the authors concluded that zirconia would be the material of choice in the esthetic area, based on its color and the in vitro results.²⁴

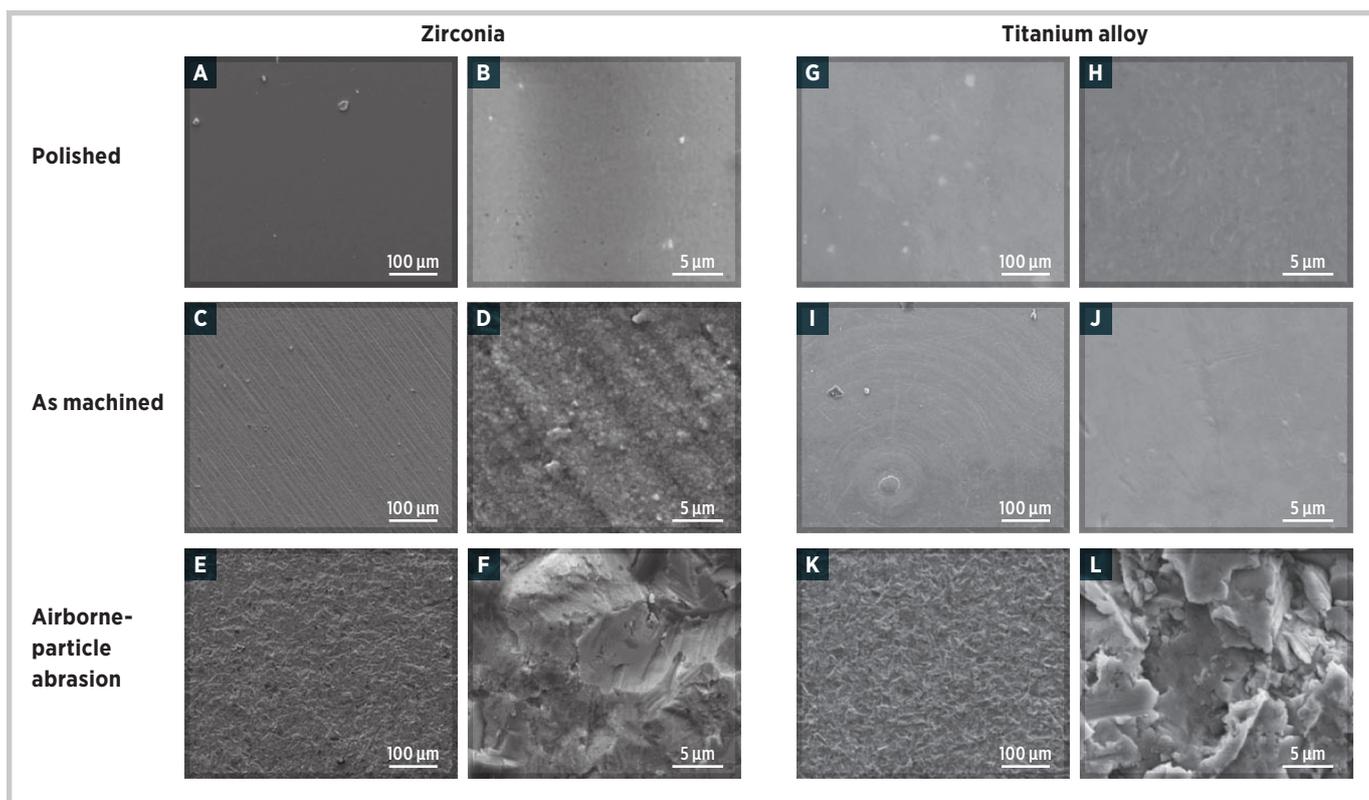


Fig 5. Representative scanning electron microscopic images of polished, machined, or sandblasted surfaces of zirconia and titanium alloy (original magnifications 500× [A, C, E, G, I, K] and 10,000× [B, D, F, H, J, L]). (Reprinted from Nothdurft et al with permission from Wiley.²⁵)

Nothdurft et al attempted to evaluate the proliferation and adherence of epithelial cells and fibroblasts on different substrates (zirconia and titanium alloy) prepared with similar surface topographies.²⁵ Special attention was paid to the investigation of water contact angle and surface roughness. On zirconia, polishing produced a smooth topography, machining produced a microgrooved structure, and sandblasting with 110- μm airborne alumina particles resulted in a very rough surface. In contrast, on titanium alloy, machining and polishing produced similar smooth surfaces, whereas sandblasting produced a very rough surface (Fig 5).²⁵

After investigating the contact angle, the authors reported that polishing of the substrates resulted in better wetting for the titanium alloy, while the machining resulted in a similar contact angle. However, sandblasting increased the contact angle and subsequently reduced the wettability of both titanium and zirconia surfaces.²⁵

Energy-dispersive X-ray spectroscopy indicated that polished titanium surfaces had an average surface roughness of about 10 nm, the machined surfaces had an average roughness determinant of about 69 nm, and sandblasted surfaces had an average roughness of about 1.514 μm . In contrast, machined zirconia had an even rougher surface value of 198.8 nm. After sandblasting, the average roughness of zirconia was approximately 1.021 μm .²⁵

With regard to cell proliferation, human gingival fibroblasts seem to favor zirconia in general. The highest numbers of cells were detected on day 3 in the sandblasted zirconia group, but polished zirconia delivered similar cell numbers. In contrast,

epithelial cell proliferation favored rough surfaces, especially titanium. Larger epithelial cells favored smooth surfaces, especially titanium.²⁵ Use of vinculin distribution analysis to determine the adhesion quality of the cells showed that epithelial cells favor titanium alloy, especially polished surfaces, while fibroblast adhesion favors rough surfaces.²⁵

Moon et al studied the adherence of human gingival fibroblasts to abutments with different surfaces.²⁶ They reported that the adhesion strength of fibroblasts improves with time, implying that manipulation and disruption during the healing process might halt or reverse these positive findings.

In another in vitro study, Baltrikienė et al investigated the tissue response to laser-modified titanium transmucosal abutments.²⁷ The specimens were polished, sandblasted, or laser ablated in different patterns (Fig 6). The results indicated that the adhesion of human gingival fibroblasts was significantly better on laser-ablated titanium surfaces than on smooth or sandblasted specimens. Fibroblast proliferation on the different titanium substrates was compared after 24, 48, and 72 hours of culture. While smooth titanium surfaces showed the greatest number of cells, all specimens showed increases in numbers of human gingival fibroblasts in a time-dependent manner.²⁷ The results with regard to fibroblast proliferation contradict the results reported by Yang et al after ultraviolet irradiation of zirconia abutments.²³

In an in vitro experiment, Xing et al analyzed the results of different surface modifications on titanium by using cathodic polarization in organic acids to roughen surfaces and produce surface hydride.²⁸ The authors utilized 3 organic acids (oxalic

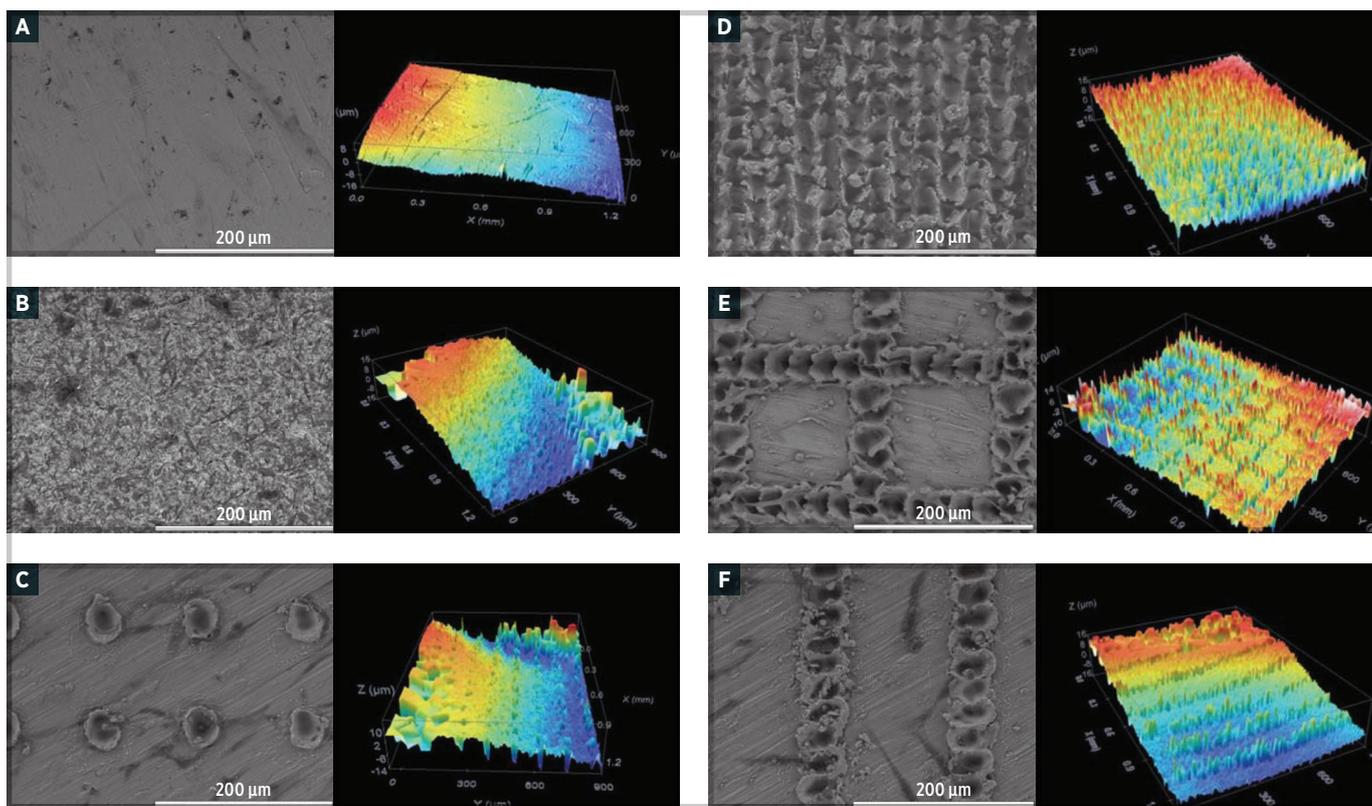


Fig 6. Titanium specimens with different surface topographies and roughness levels. A. Polished. B. Sandblasted. C. Separated perforated structures. D. Overlapping laser-ablated perforated structures arranged in all directions. E. Gridlike perforated structures. F. Overlapping laser-ablated perforated structures arranged in straight rows. (Reprinted from Baltriukienė et al with permission from Wiley.²⁷)

acid, tartaric acid, and acetic acid) and noted that oxalic acid modified the surface topography of the titanium more than the other acids. The organic acids used in cathodic polarization had positive effects on both cell size and cell number, but the results were not significant compared to the control group.

Conclusion

The hypothesis of this literature review was that utilization of abutments with surface topography and chemistry similar to those of natural teeth will produce transmucosal attachments that mimic those in nature, thereby improving functional and esthetic results. Within the limitations of this review, it can be concluded that soft tissue integration around implant abutments is possible. Fibroblast insertion into the abutment surface will eliminate the physical gap between soft tissue and the transmucosal components.

The longevity of this type of integration and the ways to achieve ideal abutment surface topography need further research. The degree of roughness of an abutment surface, the methods utilized in achieving the surface topography, and the chemistry of dental abutment materials are some of the factors that may affect the soft tissue response of the abutment-crown complex. On the other hand, violating the surface roughness threshold of $0.4 \mu\text{m}$ increases the affinity of microorganisms and the risk of peri-implant diseases, because increased roughness of the transmucosal components significantly increases the pathogenicity of the microorganisms around dental implants.²⁹

An additional factor influencing the adhesion of fibroblasts is the hydrophilicity of the surfaces of the prosthetic components of dental implants. Perpendicular collagen fiber organization against the transmucosal interface can be achieved on hydrophilic surfaces. Ultraviolet treatment to improve the surface wettability of implant abutments may be a promising in-office method for improving soft tissue seal, vascularity, and cellular proliferation as well as reducing inflammatory response, ultimately contributing to the stability of the soft tissue seal and achievement of a natural-looking restoration.

Finally, the “one abutment–one time” concept must be followed to achieve superior soft tissue attachment. Disconnection and reconnection of implant prosthetic components may disrupt established soft tissue integration.

Author information

Dr Al Rezk is in private practice in Visalia, California, and completed a master of science degree in dental implantology, Dental School, Johann Wolfgang Goethe–University of Frankfurt, Frankfurt am Main, Germany, where Dr Trimpou is an assistant professor, Department of Oral Surgery and Implantology; Dr Lauer is the head, Department of Prosthodontics; Dr Weigl is the head, Department of Postgraduate Education, and program director, Master of Science in Oral Implantology Program; and Dr Krockow is an academic manager, Master of Science in Oral Implantology Program.

References

1. Gandolfi MG, Taddei P, Siboni F, et al. Micro-topography and reactivity of implant surfaces: an in vitro study in simulated body fluid (SBF). *Microsc Microanal*. 2015;21(1):190-203.
2. Naves MM, Menezes HH, Magalhães D, et al. Effect of macrogeometry on the surface topography of dental implants. *Int J Oral Maxillofac Implants*. 2015;30(4):789-799.
3. Myshin HL, Wiens JP. Factors affecting soft tissue around dental implants: a review of the literature. *J Prosthet Dent*. 2005;94(5):440-444.
4. Iglhaut G, Schwarz F, Winter RR, Mihatovic I, Stimmelmayer M, Schliephake H. Epithelial attachment and downgrowth on dental implant abutments—a comprehensive review. *J Esthet Restor Dent*. 2014;26(5):324-331.
5. Linkevicius T, Apse P. Influence of abutment material on stability of peri-implant tissues: a systematic review. *Int J Oral Maxillofac Implants*. 2008;23(3):449-456.
6. Bosshardt DD, Selvig KA. Dental cementum: the dynamic tissue covering of the root. *Periodontol*. 1997;13(1):41-75.
7. Berglundh T, Lindhe J, Ericsson I, Marinello CP, Liljenberg B, Thomsen P. The soft tissue barrier at implants and teeth. *Clin Oral Implants Res*. 1991;2(2):81-90.
8. Rompen E, Domken O, Degidi M, Farias Pontes AE, Piattelli A. The effect of material characteristics, of surface topography and of implant components and connections on soft tissue integration: a literature review. *Clin Oral Implants Res*. 2006;17(Suppl 2):55-67.
9. Ericsson I, Giargia M, Lindhe J, Neiderud AM. Progression of periodontal tissue destruction at splinted/non-splinted teeth. An experimental study in the dog. *J Clin Periodontol*. 1993;20(10):693-698.
10. Kawahara H, Kawahara D, Mimura Y, Takashima Y, Ong JL. Morphologic studies on the biologic seal of titanium dental implants. Report II. In vivo study on the defending mechanism of epithelial adhesion/attachment against invasive factors. *Int J Oral Maxillofac Implants*. 1998;13(4):465-473.
11. Hansson HA, Albrektsson T, Brånemark PI. Structural aspects of the interface between tissues and titanium implants. *J Prosthet Dent*. 1983;50(1):108-113.
12. Chavrier C, Couble ML, Hartmann DJ. Qualitative study of collagenous and noncollagenous glycoproteins of the human healthy keratinized mucosa surrounding implants. *Clin Oral Implants Res*. 1994;5(3):117-124.
13. Moon IS, Berglundh T, Abrahamsson I, Linder E, Lindhe J. The barrier between the keratinized mucosa and the dental implant. *J Clin Periodontol*. 1999;26(10):658-663.
14. Subramani K, Jung RE, Molenberg A, Hammerle CH. Biofilm on dental implants: a review of the literature. *Int J Oral Maxillofac Implants*. 2009;24(4):616-626.
15. Hahnel S, Wieser A, Lang R, Rosentritt M. Biofilm formation on the surface of modern implant abutment materials. *Clin Oral Implants Res*. 2015;26(11):1297-1301 [epub July 24, 2014].
16. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants*. 1986;1(1):11-25.
17. Schupbach P, Glauser R. The defense architecture of the human periimplant mucosa: a histological study. *J Prosthet Dent*. 2007;97(6 Suppl):S15-S25 [erratum: 2007;99(3):167].
18. Schwarz F, Mihatovic I, Becker J, Bormann KH, Keeve PL, Friedmann A. Histological evaluation of different abutments in the posterior maxilla and mandible: an experimental study in humans. *J Clin Periodontol*. 2013;40(8):807-815.
19. Wennerberg A, Sennerby L, Kultje C, Lekholm U. Some soft tissue characteristics at implant abutments with different surface topography. *J Clin Periodontol*. 2003;30(1):88-94.
20. Nevins M, Kim DM, Jun SH, Guze K, Schupbach P, Nevins ML. Histologic evidence of a connective tissue attachment to laser microgrooved abutments: a canine study. *Int J Periodontics Restorative Dent*. 2010;30(3):245-255.
21. Iglhaut G, Becker K, Golubovic V, Schliephake H, Mihatovic I. The impact of dis-/reconnection of laser microgrooved and machined implant abutments on soft- and hard-tissue healing. *Clin Oral Implants Res*. 2013;24(4):391-397.
22. Kloss FR, Steinmüller-Nethl D, Stigler RG, Ennemoser T, Rasse M, Hächl O. In vivo investigation on connective tissue healing to polished surfaces with different surface wettability. *Clin Oral Implants Res*. 2011;22(7):699-705.
23. Yang Y, Zhou J, Liu X, Zheng M, Yang J, Tan J. Ultraviolet light-treated zirconia with different roughness affects function of human gingival fibroblasts in vitro: the potential surface modification developed from implant to abutment. *J Biomed Mater Res B Appl Biomater*. 2015;103(1):116-124 [epub April 28, 2014].
24. Kim YS, Ko Y, Kye SB, Yang SM. Human gingival fibroblast (HGF-1) attachment and proliferation on several abutment materials with various colors. *Int J Oral Maxillofac Implants*. 2014;29(4):969-975.
25. Nothdurft FP, Fontana D, Ruppenthal S, et al. Differential behavior of fibroblasts and epithelial cells on structured implant abutment materials: a comparison of materials and surface topographies. *Clin Implant Dent Relat Res*. 2015;17(6):1237-1249 [epub July 26, 2014].
26. Moon YH, Yoon MK, Moon JS, et al. Focal adhesion linker proteins expression of fibroblast related to adhesion in response to different transmucosal abutment surfaces. *J Adv Prosthodont*. 2013;5(3):341-350.
27. Baltriukienė D, Sabaliauskas V, Balčiūnas E, et al. The effect of laser-treated titanium surface on human gingival fibroblast behavior. *J Biomed Mater Res A*. 2014;102(3):713-720.
28. Xing R, Salou L, Taxt-Lamolle S, Reseland JE, Lyngstadaas SP, Haugen HJ. Surface hydride on titanium by cathodic polarization promotes human gingival fibroblast growth. *J Biomed Mater Res A*. 2014;102(5):1389-1398.
29. Quiryneen M, Bollen CM, Papaioannou W, Van Eldere J, van Steenberghe D. The influence of titanium abutment surface roughness on plaque accumulation and gingivitis: short-term observations. *Int J Oral Maxillofac Implants*. 1996;11(2):169-178.