



Biofilm Related to Dental Implants

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Although bacteria are often perceived as being harmful to the human body causing diseases such as syphilis and tuberculosis, it is important to note that periodontal diseases are infections that originate from indigenous bacteria. Disease occurs when the harmony between the host and the microbiota is disrupted, particularly in a susceptible host or when the microorganism is highly pathogenic.

Peri-implant diseases comprise inflammatory reactions in the host tissues and include peri-implant mucositis or peri-implantitis. Peri-implant mucositis, also called “ailing implant,” is defined as a reversible inflammation localized to the soft tissues with no signs of supporting bone loss.¹⁻⁴ Peri-implant mucositis may resolve by itself or persist for an undetermined period of time with the possibility of developing peri-implantitis and implant failure. Peri-implantitis refers to a destructive inflammatory reaction with evidence of loss of supporting bone around a failing but functional implant.^{1-3,5} A failed implant is defined as one that exhibits clinical mobility, pain on function, bone loss more than half of the total length of the implant, or uncontrolled exudate.⁶

The timing at which implant failures occur represents different physi-

Oral biofilm-related diseases such as periodontal and peri-implant diseases are unique infections in that they develop from the resident indigenous microflora. As more implants are nowadays being placed, clinicians may encounter more complications. Therefore, understanding the etiology is warranted to establish adequate

diagnosis and provide proper treatment. This article focuses on understanding peri-implant microbiology and its roles in peri-implant diseases. (Implant Dent 2010;19:387-393)

Key Words: *implant, microbiology, bacteria, peri-implantitis, peri-mucositis, biofilm*

ological processes. Hence, an early implant failure indicates an initial lack of osseointegration due to an inability to establish an intimate bone-to-implant contact. Various factors may contribute to early implant failures such as premature loading, surgical trauma, or impaired healing response.^{7,8} Late failure, on the other hand, occurs after initial integration, physiological remodeling, and loading. Causes of late failures include overloading and bacterial infection (e.g., peri-implantitis)⁹ with most failures occurring after the first year of loading.^{10,11} In fact, biofilms have been associated with almost 65% of infectious diseases such as periodontal and peri-implant diseases.¹²

Because the role of bacterial biofilm in peri-implant diseases has been recognized, knowledge of the microbiology around dental implants is the essence of adequate diagnosis and treatment of these diseases. This article focuses on understanding the development of oral biofilms around dental implants and their role in peri-implant diseases.

BIOFILM FORMATION AROUND DENTAL IMPLANTS

After exposure of an osseointegrated implant in the oral cavity through a transmucosal abutment, an acquired pellicle is formed on the implant surface

through selective adsorption of the environmental macromolecules such as α -amylase and serum albumin.¹³ This pellicle is derived from components in the saliva, as well as bacterial and host tissue products. It acts as a substrate for bacterial colonization, which occurs as early as 30 minutes after implant exposure in the oral cavity.¹⁴ In comparison to natural teeth, the acquired pellicle on dental implants has a lower albumin adsorption capability, which according to some authors contributed to the lower plaque formation around implants.¹⁵

Biofilm represents an organized structure in which microorganisms interact metabolically as a community.

Biofilm formation around implants occurs in a similar way as teeth. After formation of the acquired pellicle, bacterial attachment with initial colonizers followed by cell-to-cell adhesion with secondary colonizers occurs on the implant surface.¹⁶ Biofilms are the preferred method of growth for most bacteria because they facilitate exchange of nutrients and protect the bacterial community from competing microorganisms.¹⁷ Moreover, biofilms also contribute to the spread of antibiotic resistance.¹⁶

PERI-IMPLANT HEALTH

Peri-implant health is defined as an implant that demonstrates no mobility,

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<2 mm of radiographic bone loss from the initial surgery with no pain on function or history of exudate.¹⁸ Similar to the healthy periodontium around natural teeth, the microorganisms associated with healthy implants are predominantly Gram-positive cocci and rods microorganisms.^{14,19–23} The dominant species are members of the yellow and purple complexes or are independent of the complexes such as *Actinomyces naeslundii* or *Actinomyces viscosus*.^{24–26} Gram-negative bacteria can be found in smaller proportions and include *Prevotella intermedia*, *Porphyromonas gingivalis*, *Tannerella forsythia*, *Prevotella nigrescens*, and *Campylobacter rectus*.²⁴ This suggests that certain species are indigenous, host-compatible organisms.

As demonstrated in an experimentally induced peri-implant mucositis study in humans, plaque accumulation and development of peri-implant mucositis were comparable at implant and natural teeth sites.^{27,28} Interestingly, with a similar amount of plaque accumulation, implant sites had increased host response and proinflammatory cytokine production compared with that found in teeth,^{29,30} suggesting that implants may act as a foreign body.

Moreover, the composition of the supra- and submucosal microflora is similar around healthy implants.³¹ On the other hand, bacterial species in the supra- and subgingival plaque around teeth are rather different. The subgingival microflora is initially derived from the supragingival plaque and becomes more anaerobic as the oxygen pressure in the environment is reduced.³² The supragingival plaque around teeth could serve as a reservoir to spread or reinfect subgingival sites.^{33,34}

TRANSITION FROM HEALTH TO PERI-IMPLANT DISEASES

An adequate permucosal seal of the soft tissue to the implant surface protects the base of the sulcus against the penetration of chemical and bacterial substances. With the loss of this initial seal, the peri-implant mucosa may progress from health to mucositis and possibly to peri-implantitis. As the peri-implant tissues undergo the process from a state of health to that of disease, differences in bacterial num-

bers and morphotypes can be found. A shift from a Gram-positive facultative dominated flora to a Gram-negative anaerobic biofilm occurs.¹⁹

The failing implant is characterized by a greater proportion of red (*P. gingivalis*, *Treponema denticola*, and *T. forsythia*) and orange (*P. intermedia* and *Fusobacterium nucleatum*) complex, as well as *Aggregatibacter actinomycetemcomitans* and *Eikenella corrodens* with a lower proportion of the flora associated with health.^{9,31,35–39} Hence, the main differences between health and disease are in the proportions of Actinomyces, orange and red complex species. Furthermore, increasing peri-implant probing depth has been significantly associated with higher total anaerobic cultivable microbiota and the frequency of detection of *P. gingivalis*.⁴⁰

Van Winkelhoff *et al* studied the early colonization of the peri-implant pockets by putative periodontal pathogens in 20 partially edentulous patients. The authors found that most periodontal pathogens (*P. gingivalis*, *F. nucleatum*, *P. intermedia*, and *T. forsythia*) were already identified as early as 6 months after loading. In particular, *P. gingivalis* was significantly associated with the presence of fistulas and implant loss. The study also demonstrated that although 2 patients exhibited *A. actinomycetemcomitans* during their baseline examination, *A. actinomycetemcomitans* was not isolated from any implant pocket during the experimental period.⁴¹

Other microorganisms such as *Staphylococcus aureus*, *Candida albicans*, and enteric rods have also been associated with peri-implantitis.^{26,38,42,43} *S. aureus* has high adhesion to titanium surfaces,⁴⁴ and its presence has been associated with suppuration and bleeding on probing.⁴⁵ *C. albicans* is the most common fungus found in the oral cavity, and its presence is strongly associated with oral candidiasis especially in patients wearing dentures.^{46,47} *C. albicans* has high adhesion to dental implants⁴⁶ although an in vitro study showed lower levels of this microorganism on sandblasted titanium surfaces.⁴³ Infection of dental implants with these opportunistic microorganisms should be recognized

especially in the immunocompromised patient.⁴⁸

HISTORY OF PERIODONTITIS

Because the implicated microorganisms are essentially periodontal pathogens, are patients with a history of chronic periodontitis at higher risk for peri-implantitis? As discussed previously, the microbiota associated with healthy and failing implants are similar to the one observed in periodontal health and disease around the teeth.^{19,24,49} The indigenous oral bacteria on the remaining teeth serve as reservoirs for colonization on the implant surface, which explains the similarity of the biofilm composition around implants and natural teeth within the same individual.^{50–55} In periodontally susceptible patients, the coexistence of teeth and implants create a local environment in which subgingival periodontal pathogens around teeth can cause disease around the implant.⁵⁶

Recent systematic reviews agreed that a history of periodontitis represents an increased risk for implant failure, with odds ratios ranging between 3.1 and 4.7.^{57–59} In a 10-year prospective study, Karoussis *et al*⁶⁰ evaluated the incidence of peri-implantitis in 53 patients. Subjects with a history of chronic periodontitis showed a higher incidence of peri-implantitis (28.6%) in comparison with subjects without previous periodontitis. In agreement with Karoussis *et al*, Lee *et al*²⁴ also found that subjects with a history of periodontal disease harbored increased periodontal pathogens.

In contrast to these findings, Ellegaard *et al*⁶¹ concluded that implant success remains high (95%) in periodontally compromised patients exhibiting good oral hygiene. In a longitudinal study of partially edentulous patients treated for generalized aggressive and chronic periodontitis, Mengel *et al* examined the microflora after 5 and 3 years of implant placement, respectively. Healthy conditions around both teeth and implants were found with a similar distribution of the microorganisms.⁶² It seems that important factors to consider in the success of implants are good oral hygiene, treatment of periodontal condition, and appropriate periodontal maintenance program.^{63–66}

Patients with a history of chronic periodontitis may still be at increased risk for peri-implant diseases because of host-related factors.⁶⁷ As a consequence, adequate periodontal infection control is important before dental implant placement to help prevent bacterial complications.⁴¹

SURFACE ROUGHNESS

Increased surface roughness has been associated with increased osseointegration of the dental implant.⁶⁸⁻⁷⁰ Conversely, a higher surface roughness with a Ra value $>0.2 \mu$ increases biofilm formation^{71,72} and thus contributes to spontaneous progression of peri-implantitis lesions.^{65,73-75} Berglundh *et al*⁷⁵ performed an experimental study in dogs and showed that increased plaque and faster progression of peri-implantitis were found in rough surface compared with polished machined surface implants. In agreement with Berglundh *et al*, Amarante *et al*⁷⁶ found that machined surface implants harbored significantly less bacteria than plasma-sprayed implants and had increased amount of *Streptococcus sp.* compared with brushed surfaces.

Abutment surface roughness may also impact the accumulation of biofilm. With increasing abutment surface roughness, higher supramucosal plaque accumulation is noted.⁷⁷ Quirynen *et al* examined 9 patients and found that abutments with a rough surface harbored more bacterial pathogens and less coccoid microorganisms than that on smooth surfaces. In fact, up to 25 times more bacteria was found in the supramucosal plaque of rough abutments compared with smooth abutment.⁷⁸ Interestingly, this increase is not observed in submucosal areas, suggesting that periodontal pathogens in this area were more influenced by the patient's oral hygiene rather than surface texture.^{77,78}

Although a relationship between surface roughness and plaque formation has been assessed, other authors reported conflicting results. Martins *et al*⁷⁹ conducted an experimental peri-implantitis study in dogs, and their data suggested that different surface roughness implants were equally susceptible to the accumulation of plaque and to peri-implantitis. In addition,

Esposito *et al*⁴ in a literature review concluded that roughened implant abutment surfaces caused by different maintenance techniques were not associated with increased implant complications. It seems from these studies that the impact of surface roughness is dependent on the individual patient, with personal and professional oral hygiene exerting a great influence.

TREATMENT INFLUENCE ON MICROBIOTA

Treatment of dental implant-associated infections consists of an anti-infective protocol that can be achieved through mechanical debridement of the implant surface or chemical treatment including local and systemic antibiotics. The selected treatment modality depends on the established diagnosis of peri-implant mucositis or peri-implantitis. Treatment success is assessed using outcome measures such as reduction of inflammation, probing depth, and pathogenic bacteria.⁸⁰ Nonetheless, the presence of a specific bacteria had little or no value in predicting treatment failure.⁸¹

In a recent literature review, non-surgical mechanical therapy was effective in treating peri-implant mucositis with improved results observed in conjunction with an antimicrobial mouth rinse.¹² A reduction in the proportion of pathogenic species after mechanical therapy has been reported.⁸²

However, nonsurgical treatment of sites with peri-implantitis was not found to be effective at reducing inflammation, pathogenic microorganisms, and bleeding on probing.¹² The addition of antimicrobial mouth rinse in this nonsurgical treatment of peri-implantitis only provided minimal beneficial effects.^{12,83} On the other hand, the use of local drug delivery such as minocycline and tetracycline to treat peri-implantitis has generated reduced levels of *T. forsythia*, *P. gingivalis*, and *T. denticola*, with the most effect on *A. actinomycetemcomitans*.⁸¹ After surgical treatment of sites with peri-implantitis such as open debridement, a reduction in the proportion of red complex species was observed.⁸²

In the past decades, laser therapy such as diode, CO₂, and Er:YAG laser

has gained popularity based on the rationale of surface decontamination, hemostatic properties, calculus removal, and bactericidal effects.⁸⁴⁻⁸⁶ However, only minor clinical and microbiological improvement has been reported.^{12,87} Further studies are mandated to evaluate the beneficial effects of laser therapy.

CONCLUSION

Implant complications have significant health and financial implications to both the patient and clinician. Peri-implantitis has a multifactorial etiology in which oral biofilm is a recognizable etiologic agent. It is well demonstrated that the combination of multiple pathogenic bacteria increases the risk of peri-implant diseases and can better determine disease activity rather than the identification of a single microorganism.^{52,88} The reduction of the bacterial load to a level compatible with health is an important aspect of implant therapy. With the emergence of new technologies, identification of bacteria in the oral cavity continues to improve. It is likely that new pathogens may emerge from uncultured microorganisms.

Disclosure

The authors claim to have no financial interests, either directly or indirectly, in the products or information listed in the article.

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ID Abstract Translations

GERMAN / DEUTSCH

AUTOR(EN): Angie Lee, DMD, Hom-Lay Wang, DDS, MSD, PhD

Biofilm in Verbindung mit Zahnimplantaten

ZUSAMMENFASSUNG: Erkrankungen in Verbindung mit oralem Biofilm, so wie beispielsweise Erkrankungen des Zahnbetts und des Implantatumfelds sind spezifische Infektionen dadurch, dass sie sich aus der ureigenen Mikroflora entwickeln. Da heutzutage häufiger Implantate eingepflanzt werden, kann es auch für die behandelnden Kliniker zu mehr Komplikationen kommen. Daher ist ein Verständnis der Ätiologie erforderlich, um eine entsprechende Diagnose vornehmen und richtig diagnostizieren und behandeln zu können. Die vorliegende Arbeit konzentriert sich auf die Vermittlung eines Verständnisses der Mikrobiologie im das Implantat umgrenzenden Gewebe sowie dessen Beteiligung an Erkrankungen im das Implantat umlagernden Gewebe.

SCHLÜSSELWÖRTER: Implantat, Mikrobiologie, Bakterien, Peri-Implantitis, Peri-Mukositis, Biofilm

SPANISH / ESPAÑOL

AUTOR(ES): Angie Lee, DMD, Hom-Lay Wang, DDS, MSD, PhD

Biopelícula relacionada a los implantes dentales

ABSTRACTO: Las enfermedades relacionadas con la biopelícula oral tales como las enfermedades periodontales y periimplante son infecciones especiales ya que aparecen de la microflora indígena residente. A medida que se colocan más implantes en la actualidad, los clínicos podrían encontrar más complicaciones. Por lo tanto, entender la etiología es necesario para poder establecer un diagnóstico adecuado y ofrecer un tratamiento correcto. Este trabajo se concentra en entender la microbiología periimplante y sus papeles en las enfermedades periimplante.

PALABRAS CLAVES: Implante, microbiología, bacteria, periimplantitis, perimucositis, biopelícula

PORTUGUESE / PORTUGUÊS

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Biofilme Relacionado a Implantes Dentários

RESUMO: As doenças orais relacionadas a biofilme tais como as doenças periodontais e de peri-implante são infecções únicas pelo fato de que se desenvolvem a partir da microflora residente nativa. À medida que mais implantes estão sendo colocados hoje

em dia, os clínicos podem encontrar mais complicações. Portanto, entender a etiologia é justificado a fim de estabelecer diagnóstico adequado e fornecer tratamento apropriado. Este artigo focaliza o entendimento da microbiologia de peri-implante e seus papéis em doenças de peri-implante.

PALAVRAS-CHAVE: Implante, microbiologia, bactérias, peri-implantite, perimucosite, biofilme

RUSSIAN / РУССКИЙ

АВТОРЫ: Angie Lee, доктор стоматологии, Hom-Lay Wang, доктор хирургической стоматологии, магистр стоматологии, доктор философии

Биопленки и зубные имплантаты

РЕЗЮМЕ. Заболевания полости рта, связанные с биопленками, такие как пародонтит и периимплантатное заболевание, являются уникальными инфекциями, поскольку они возникают из-за состояния постоянной резидентной микрофлоры. Поскольку на сегодняшний день устанавливается все больше имплантатов, врачи могут столкнуться и с большим количеством осложнений. Поэтому понимание этиологии данных заболеваний обеспечивает постановку правильного диагноза и проведение надлежащего лечения. В данной статье основное внимание уделяется вопросам периимплантатной микробиологии и ее роли в развитии периимплантатных заболеваний.

КЛЮЧЕВЫЕ СЛОВА: имплантат, микробиология, бактерия, периимплантат, перимукозит, биопленка

TURKISH / TÜRKÇE

YAZARLAR: Angie Lee, DMD, Hom-Lay Wang, DDS, MSD, PhD

Dental İmplantlar ile Bağlantılı Biyofilm

ÖZET: Periodontal ve peri-implant hastalıklar gibi oral biyofilm ile bağlantılı hastalıklar, olgunun kendi doğal mikroflorasından geliştikleri için benzersiz enfeksiyonlardır. Günümüzde implant uygulaması daha da sıklıkla olduğundan klinisyenlerin daha fazla komplikasyonlar ile karşılaşmaları olasıdır. Bu nedenle, tanının yeterli ve tedavinin uygun olabilmesi için etyolojinin anlaşılması gerekir. Bu yazı, peri-implant mikrobiyolojisini ve bunun peri-implant hastalıklarındaki rolünü anlamak amacıyla tasarlandı.

ANAHTAR KELİMELELER: İmplant, mikrobiyoloji, bakteri, peri-implantit, peri-mukozit, biyofilm

JAPANESE / 日本語

デンタルインプラント関連バイオフィーム

共同研究者氏名: アンジー・リー (Angie Lee) DMD, ホムレイ・ワング (Hom-Lay Wang) DDS, MSD, PhD

研究概要:

歯周病やインプラント周囲病などの口腔微生物膜関連病は定住常在微生物叢によって引き起こされる独自の感染症である。近年多数のインプラントが埋入施術されるにつれて、臨床医はさまざまな合併症増加に遭遇する可能性がある。そこで適確な診断ならびに適切な治療処置を確立するためには、病因学の理解が妥当とみなされる。当文献はインプラント周辺微生物学の理解とインプラント周囲病におけるその役割に焦点を当てる。

キーワード: インプラント、微生物学、バクテリア、インプラント周囲炎、インプラント周囲粘膜炎、バイオフィーム

CHINESE / 中国語

與牙科植體相關的生物膜

作者: Angie Lee, DMD, Hom-Lay Wang, DDS, MSD, PhD

摘要:

牙周和植體周圍疾病等口腔生物膜相關疾病屬於從固有性原生菌種衍生的特有感染。由於植牙日益普及，臨床醫師可能遭遇更多併發症。因此，必須瞭解病因以確定充分的診斷並提供適當的治療。本報告著重於瞭解植體周圍微生物學，以及其在植體周圍疾病中所扮演的角色。

關鍵字: 植體、微生物學、細菌、植體周圍炎、植體周圍粘膜炎、生物膜

KOREAN / 한국어

균막 관련 치과 임플란트

저자: 앤지 리 (Angie Lee), DMD, 음 레이 왕 (Hom-Lay Wang), DDS, MSD, PhD

요약:

치주 및 임플란트 주위 질환과 같은 구강 균막 관련 질환은 상재 미생물총으로부터 발전된다는 점에서 특징적인 감염 질환이다. 임플란트 식립이 더욱 많아지고 있는 현재, 임상 의들은 합병증에 접하게 될 가능성이 더욱 많아지고 있다. 따라서, 병인을 이해하는 것은 적절한 진단과 적합한 치료를 가능하게 한다. 본 연구는 임플란트 주변 미생물학 및 임플란트 주변 질환에서 미생물의 작용을 이해하는데 목적을 두고 진행하였다.

키워드: 임플란트, 미생물학, 세균, 임플란트 주위염, 점막 주위염, 균막