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Review Article

The biofilm conundrum in orthodontics: Investigating the role of the bonding procedure

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ABSTRACT

This article explores the conundrum of biofilm formation in orthodontics, its impact on oral health, and the role of the bonding procedure. Biofilms are resilient structures formed through stages like attachment, adhesion, growth, and maturation, with the extracellular matrix (EPS) playing a vital role. The bonding procedure unintentionally creates surfaces where bacteria thrive, leading to biofilm development. Factors like oral hygiene, diet, and bracket design influence biofilm formation. Maintaining oral hygiene during orthodontic treatment can be challenging due to food trapping and cleaning difficulties. Strategies to minimize biofilms involve patient education, improved bonding techniques, and antimicrobial agents. Biofilms can lead to dental decay, gingivitis, periodontitis, and white spot lesions. Combating biofilms requires collaboration, patient education, and ongoing research. Improved management can lead to better oral health outcomes for orthodontic patients.

1. Introduction

Orthodontics has made significant strides in recent decades, offering effective solutions to achieve optimal dental alignment and improve oral health. As more patients opt for orthodontic treatment, it becomes crucial to explore the potential challenges associated with these procedures.[1] One such issue is the formation of biofilms around orthodontic appliances, posing a significant conundrum for both patients and orthodontists.[2] This article delves into the world of biofilms in orthodontics, exploring their impact on oral health and investigating the role of the bonding procedure in their formation.

2. Discussion

2.1. Formation of biofilms

The formation of biofilms typically occurs in several stages:

1. Attachment: Initially, individual microorganisms in the surrounding environment adhere to a surface through weak interactions. These microorganisms can be free-floating in a liquid or come into contact with the surface of the air.[3]
2. Adhesion: Once attached to the surface, the microorganisms start to produce adhesive substances that allow them to firmly stick to the surface.

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This is often facilitated by the production of slimy extracellular polymeric substances (EPS).[3]

3. Growth and Colonization: As more microorganisms attach and reproduce, the biofilm grows in size, eventually forming a multi-layered and complex structure.[4]
4. Maturation: The biofilm continues to develop and mature, with distinct microenvironments developing within it. Different microorganisms can occupy different niches based on factors like oxygen availability, nutrient gradients, and pH levels.[3,4]
5. Detachment: At certain stages, some microorganisms may detach from the biofilm and disperse to form new biofilms elsewhere. This detachment aids in the spread of the biofilm to other surfaces.[4,5]
6. Extracellular Matrix (EPS): The extracellular matrix (EPS) is a key component of biofilms and plays a crucial role in their formation, maintenance, and resilience. It is a self-produced, protective, and hydrated structure that holds the biofilm together. The EPS is primarily composed of polysaccharides, proteins, nucleic acids, and lipids. This matrix acts as a barrier, preventing antimicrobial agents from penetrating and reaching the microorganisms within the biofilm.[6]
7. Biofilm Resilience: Biofilms exhibit several characteristics that make them highly resilient and difficult to eliminate.[5,6]
8. Antibiotic Resistance: The EPS and the unique microenvironments within the biofilm protect the microorganisms from antibiotics, making them significantly less susceptible to traditional antimicrobial treatments.[7]
9. Reduced Growth Rate: Inside the biofilm, microorganisms may grow at a slower rate than their planktonic (free-floating) counterparts, making them less susceptible to treatments that target actively growing cells.[7]
10. Quorum Sensing: Biofilm-forming microorganisms often communicate through quorum sensing, a process by which they release signaling molecules that regulate their behavior. This allows them to coordinate their activities and adapt to changing environmental conditions.[8]
11. Nutrient Availability: The biofilm's structure provides localized nutrient gradients, ensuring a continuous supply of essential nutrients for the microorganisms.
12. Control and Eradication: Controlling and eradicating biofilms pose significant challenges due to their resilience. Strategies to manage biofilms may involve a combination of approaches, including mechanical removal, chemical treatments, and innovative antimicrobial agents that specifically target biofilms. Researchers are continually working to develop effective methods to combat biofilms and prevent their formation in various settings, including medical devices and oral healthcare.[7]

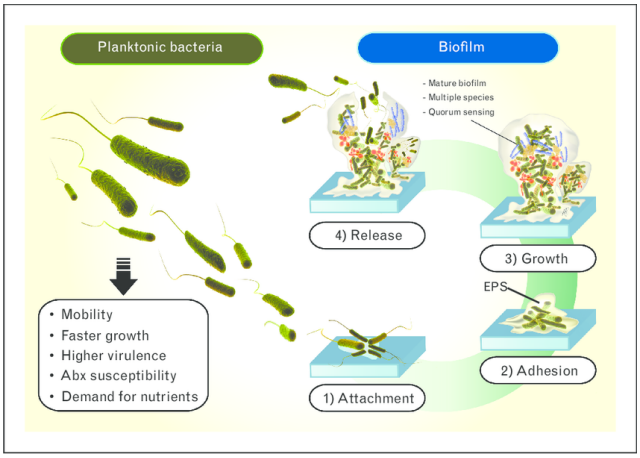

Fig. 1: https://www.researchgate.net/publication/293327988/figure/fig1/AS:38 formation-The-first-step-of-biofilm-formation-is-the-reversible-attachment-to-a.png

Understanding biofilms and their complexities is crucial for developing effective interventions to manage and prevent biofilm-related issues in diverse environments, including dental appliances and oral tissues.

2.2. The bonding procedure and biofilm formation

The bonding technique, which entails applying dental adhesives to secure brackets and wires to the teeth, is a crucial part of orthodontic therapy. However, this procedure unintentionally produces micro-gaps and rough surfaces where bacteria may cling and flourish, resulting in the creation of biofilm. Additionally, orthodontic devices can interfere with excellent oral hygiene, making it challenging for patients to maintain good oral hygiene and encouraging the buildup of plaque and debris.[9]

2.2.1. The bonding procedure

The bonding procedure is a fundamental step in orthodontic therapy, where dental adhesives are used to attach brackets and wires to the teeth. It is essential for achieving the necessary forces to move and align the teeth properly. The process typically involves the following steps:

1. Tooth Preparation: Before bonding, the teeth are cleaned and conditioned to create a suitable surface for the adhesive to adhere to. The enamel surface is etched using an acidic gel, creating a microscopically rough texture that improves the adhesive's grip.[10,11]
2. Application of Adhesive: Dental adhesives, usually in the form of resin-based composites, are applied to the bracket bases. These adhesives are specially

formulated to adhere to both the bracket and the enamel surface of the teeth.[10]

3. Placement of Brackets: The brackets are carefully positioned on the teeth, and excess adhesive is removed.[10]
4. Curing: Once the brackets are in place, a special curing light is used to harden the adhesive, ensuring a strong bond between the bracket and the tooth surface.[10,11]

2.2.2. *Biofilm formation*

As was previously discussed, the bonding process accidentally leaves the tooth enamel with micro-gaps and rough surfaces. It is difficult to eradicate these little imperfections, which provide crevices for germs to colonize and grow. The creation of biofilms may be summed up as follows:

1. Bacterial Attachment: The rough and uneven surfaces of the bonded brackets and wires come into touch with oral germs, which are prevalent in the mouth by nature. During the bonding process, some germs may be introduced.
2. Extracellular Polymeric Substance (EPS) Production: Upon attachment, the bacteria start to produce a slimy, protective matrix known as the extracellular polymeric substance (EPS). This matrix allows the bacteria to stick together and adhere to the tooth surface more firmly.
3. Microbial Growth and Biofilm Maturation: As the bacteria continue to multiply, the biofilm grows in thickness and complexity. Bacteria within the biofilm communicate through signaling molecules, a process known as quorum sensing, which helps them coordinate their activities and adapt to the environment.[12]

2.3. *Factors influencing biofilm formation:*[13]

Several factors influence biofilm formation around orthodontic appliances:

1. Oral Hygiene: Inadequate oral hygiene practices can significantly contribute to biofilm development. Patients undergoing orthodontic treatment must be educated about the importance of diligent oral care, including regular brushing, flossing, and using mouthwashes.
2. Diet: The consumption of sugary and acidic foods increases the likelihood of biofilm formation. Bacteria in biofilms produce acids that can lead to enamel demineralization and tooth decay, particularly around brackets and bands. Bracket Design: The design and material of orthodontic brackets can influence biofilm formation. Smooth-surfaced and micro-etched brackets may offer better resistance to biofilm adherence compared to conventional brackets.
3. Saliva Flow: Adequate saliva flow helps cleanse the oral cavity and reduce the accumulation of biofilms. Some orthodontic appliances may interfere with the natural flow of saliva, exacerbating the problem.

2.4. *Challenges to oral hygiene:*[14]

Maintaining excellent oral hygiene can be difficult when orthodontic equipment, like braces and wires, is present. These difficulties include:

1. Food and Debris Trapping: Brackets and wires, especially in and around the bonded regions, can trap food particles and debris. Plaque development is facilitated by the bacteria in the biofilm, whose growth is fueled by the nutrients present in the trapped debris.[13]
2. Cleaning Challenges: Patients who use orthodontic equipment may find it more difficult to properly clean their teeth. Because brackets and wires are present, regular brushing and flossing are more difficult. Plaque and debris removal may be more challenging in some places since they are tougher to access.[14]
3. Reduced Salivary capability: The normal cleaning function of saliva, which aids in neutralizing acids, washing away food particles, and maintaining dental health, might be hampered by orthodontic gear.[14]
4. Poor dental Hygiene Habits: Because cleaning around braces is more difficult, some patients may start to neglect their dental hygiene practice. As a result, there may be a higher chance of acquiring dental problems including gum disease and tooth decay.[14]

2.5. *Mitigating the impact of biofilm formation and oral hygiene challenges:*[15]

To minimize biofilm formation and maintain good oral hygiene during orthodontic treatment, patients, and dental professionals can consider the following strategies:

1. Regular Dental Check-ups: Frequent visits to the dentist or orthodontist allow for professional cleaning and assessment of oral health. Dental professionals can monitor the patient's oral hygiene progress and guide as needed.
2. Proper Oral Hygiene Routine: Patients should receive a thorough education on effective brushing and flossing techniques tailored to their orthodontic appliances. The use of specialized tools like interdental brushes and floss threaders can help clean around braces and wires more effectively.
3. Mouthwash and Fluoride: Dentists may recommend antibacterial mouthwash to help control bacterial growth and fluoride treatments to strengthen the teeth and prevent decay.

4. Dietary Considerations: Patients should be advised to avoid sticky and sugary foods that can contribute to plaque buildup and dental problems.
5. Orthodontic Device Maintenance: Patients should follow the orthodontist's instructions for maintaining and cleaning their braces or aligners. Regular cleaning of orthodontic devices helps reduce plaque buildup and bacterial adherence.

By implementing these strategies and closely monitoring biofilm formation, orthodontic patients can reduce the risk of dental issues during their treatment. Dental professionals can also explore innovative approaches to minimize micro-gaps and surface irregularities during the bonding procedure to further mitigate biofilm formation and improve overall oral health outcomes.

2.6. Impacts of biofilms on oral health[16]

Biofilm formation around orthodontic appliances can lead to several oral health issues, including:

1. Dental Decay: Biofilms create an acidic environment that can lead to enamel demineralization and the development of cavities.
2. Gingivitis and Periodontitis: The accumulation of bacteria in biofilms can cause inflammation and gum disease, including gingivitis and periodontitis.
3. White Spot Lesions: Prolonged biofilm formation can cause demineralization, resulting in white spot lesions around the brackets, causing esthetic concerns after orthodontic treatment.
4. Bad Breath: The presence of biofilms can lead to halitosis (bad breath) due to the release of volatile sulfur compounds.

2.7. Strategies to minimize biofilm formation[17,18]

While complete prevention of biofilm formation may be challenging, several strategies can help minimize its impact:

1. Patient Education: Orthodontists must educate patients about proper oral hygiene practices and the importance of maintaining regular dental check-ups during treatment.
2. Effective Bonding Techniques: Utilizing innovative bonding techniques and materials can reduce the formation of biofilms during the orthodontic bonding process.
3. Antimicrobial Agents: Incorporating antimicrobial agents into orthodontic materials may help inhibit biofilm development.
4. Regular Maintenance: Regular visits to the orthodontist for appliance adjustments and cleaning can aid in controlling biofilm buildup.[18]

A recent investigation conducted by Da-Mi Jeon[9] and colleagues has unveiled noteworthy insights into the impact of surface treatment during orthodontic bonding on Surface Roughness (SR) and Surface Wettability (SW). The study revealed that the application of acid etching led to a notable increase in both SR and SW. Conversely, the application of adhesive exhibited a contrasting effect by substantially reducing SR and SW. These alterations in surface characteristics exhibited a substantial correlation with the formation and composition of biofilms. Notably, the study highlighted the enhanced adherence of two key oral pathogens, namely S. mutans and P. gingivalis, to untreated bovine incisors and acid-etched bovine incisors characterized by rougher and more wettable surfaces, compared to adhesive surfaces featuring smoother and less wettable properties. This in vitro exploration implies a significant interplay between changes in surface properties during the orthodontic bonding procedure and the resultant biofilm formation and composition of S. mutans and P. gingivalis.

3. Conclusion

In conclusion, addressing the biofilm challenge in orthodontics requires a multidisciplinary approach involving patient education, innovative bonding techniques, and the strategic use of antimicrobial agents. Empowering patients with proper oral hygiene knowledge is vital while exploring advanced bonding materials can reduce bacterial adherence. Incorporating safe antimicrobial agents can control biofilm growth. Regular monitoring and collaboration between professionals can lead to improved treatment outcomes and better oral health for orthodontic patients. Ongoing research will continue to refine strategies to combat biofilm-related complications.

4. Conflicts of Interests

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