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Bacterial biofilm accumulation on self-ligating vs. elastomeric metal brackets: A review study

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Abstract

Objectives: This study's objective is to analyze the literature and determine whether or not self-ligating metal brackets collect more or less bacterial biofilm than elastomeric metal brackets. The assessment of scientific quality is complicated by the disparate methods used to test biofilm adhesion on brackets.

Review: Published studies attest to the high caliber of the research and the methodological soundness of a subset of the papers in the literature. It may submit them for review to the scientific and clinical communities. Conventional elastomeric brackets were found to create more biofilm retention; however, another study found no statistically significant difference between the two types of brackets (elastomeric vs. self-ligating); still another study found that elastomeric brackets had less bacterial biofilm accumulation than self-ligating brackets because self-ligating brackets have bracket channels.

Conclusion: The decision utilized by orthodontists to substitute self-ligating brackets for elastomeric ones in their clinical practice with the goal of enhancing hygiene and reducing plaque accumulation is not yet supported by scientific data.

Keywords: Bacteria; Biofilm; Brackets; Dentistry; Health outcomes; Orthodontics

1. Introduction

The oral and gingival tissues will always become colonized by microbes as a result of orthodontic treatment. The physicochemical conditions of bacterial development are changed when orthodontic appliances are used inside the mouth, resulting in both qualitative and quantitative changes[1]. The retention of dental biofilm is favored when brackets are used during orthodontic therapy. As a result, the patient develops changes in the pH of their mouth, caries development[2, 3], gingivitis[4], and periodontitis[5].

Comparing traditional brackets to metallic ligatures, the elastomer and its elastic the decomposition may be responsible for the build-up of biofilm[6, 7]. In order to solve this issue, innovative methods and materials for orthodontic equipment were developed. One such example is the self-ligating bracket, which eliminates the need for metallic or elastic ligatures to hold the orthodontic wire in place[8]. Because of their design and lack of metal and elastomeric ligatures, self-ligating brackets, according to the producers, are less prone to bacterial colonization[8, 9]. However, it is controversial if using self-ligating systems' opening and closing mechanisms and removing the ligatures from conventional brackets can lessen the adherence of microbes and the formation of biofilm. In everyday orthodontic treatment, the issue of plaque buildup around brackets persists despite advancements in bracket technology[8].

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Regarding the development of biofilms and microbe adherence for both conventional and self-ligating brackets, numerous articles throughout the years have reported varying findings. Different systems measure biofilm adhesion on brackets, which makes it difficult to assess the quality of the research[10]. In a study by Mummolo et al., distinct microbiological patterns were discovered depending on the type of brackets employed[11, 12]. The researchers took saliva samples from sixty patients, dividing them into three groups of twenty patients each (the self-ligating group, the traditional group, and the untreated control group) so that Lactobacillus sp. and S. mutans could be evaluated. During orthodontic treatment, the variety of bacteria changes over time and appears to follow distinct trends based on the type of orthodontic device[11]. Thus, it was suggested to confirm whether the traditional or self-ligating bracket design affects bacterial colony formation and adherence using a systematic review[10].

2. Bacteria Biofilm

Biofilms are incredibly complex architectural communities made by bacteria that may grow on to nearly any surface[13]. Any syntrophic group of microorganisms in which the cells adhere to one another and frequently to a surface is referred to as a biofilm[14]. The extracellular polymeric substances (EPSs) that compose up the slimy extracellular matrix surround these adhering cells[15]. The extracellular polysaccharide complex (EPS) is made up of proteins, lipids, DNA, and extracellular polysaccharides. It is produced by the cells that make up the biofilm. As a result of their three-dimensional structure and representation of a communal living for microorganisms, they have been referred to as "cities for microbes"[14, 15].

2.1. Dental biofilm

The human oral cavity is home to several diverse bacterial habitats, such as the tonsils, tongue, cheeks, hard and soft palates, and gingival sulcus[13]. Dental plaque is a type of oral microbial biofilm that forms on the surfaces of exposed teeth. It is made up of many different species closely clustered together inside an organic polymer matrix that is both bacterial and salivary in origin[16]. The pathogenic bacterial complex that results from the biofilm maturing if it is not routinely eliminated can cause periodontitis, gingivitis, and tooth cavities[17].

Bacteria attach themselves to one another and frequently to surfaces to form biofilms. An extracellular polymeric matrix that the bacteria self-produce surrounds the microorganisms. Streptococcus mutans is a significant dental biofilm-producing bacterium that produces the extracellular polysaccharide matrix. Different from planktonic cells, which float or swim in a liquid media, are the bacterial cells developing in a biofilm. Plaque biofilm-forming bacteria are sensitive to a variety of stimuli, including signals from feeding and cellular recognition of particular or non-specific attachment sites on a surface. The development and growth of oral biofilm were categorized into five stages by Marsh and Martin (Figure 1)[9, 11, 18].

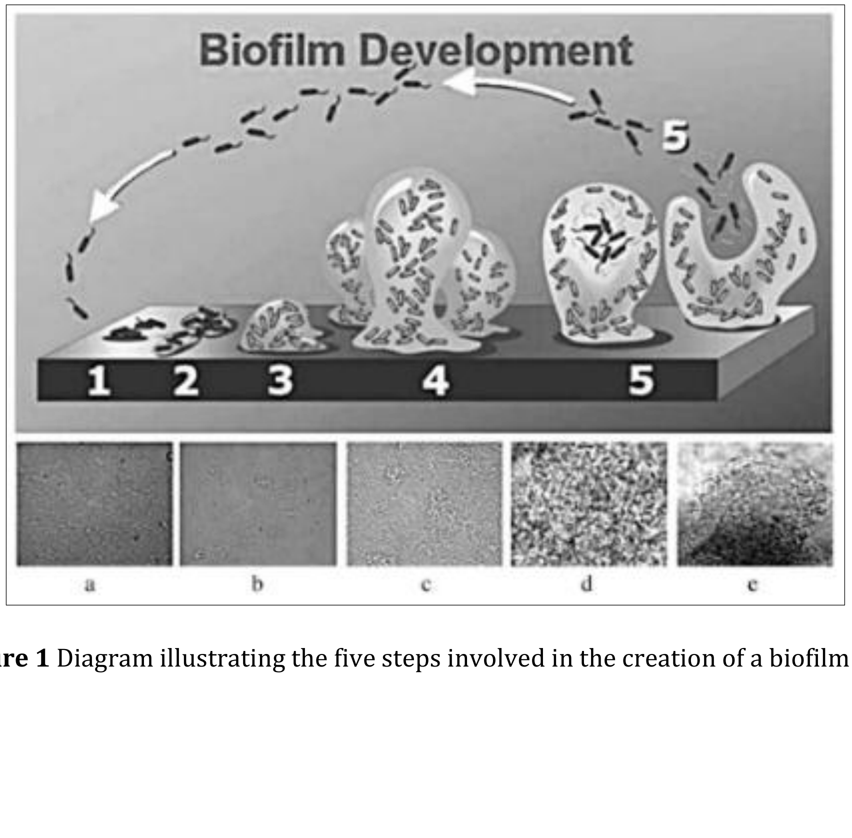

Figure 1 Diagram illustrating the five steps involved in the creation of a biofilm[19]

- Stage 1: Initial cell adhesion to the surface.
- Stage 2: The formation of EPS leads to "irreversible" more securely attached attachment.
- Stage 3: The initial stages of biofilm architecture development.
- Stage 4: The establishment of biofilm architecture.
- Stage 5: Single cells releasing the biofilm and dispersing.

Each of the five developmental stages is depicted in the bottom panels (a–e) by a photomicrograph of P. aeruginosa grown on a glass substrate in continuous flow[19].

Dental implants, dentures, gingiva, oral mucosa, enamel, dentin, cementum, restorations, carious lesions, and other surfaces can all harbor oral biofilms. Different dental plaque formation locations have different organizational and structural characteristics. Various factors, including the pH of the environment, the availability of nutrients, the presence of antimicrobial drugs, and host defense, influence the proliferation of microbes on certain oral niches[17, 20].

According to research on the microbial aetiology of different types of periodontitis, only specific bacteria found in the plaque complex are considered harmful. This theory is known as the specific plaque hypothesis. Less than 20 species of bacteria are regularly identified in higher proportions at periodontally diseased areas, despite the fact that there are hundreds of species present in periodontal pockets. These particular, highly pathogenic bacteria trigger the host's inflammatory and immunological responses, which lead to the devastation of soft tissues and bones[15, 20].

Early plaque is mostly made up of gram-positive organisms, according to Socransky and colleagues. If the plaque is left undisturbed, it matures and becomes more complicated, with a preponderance of gram-negative flora[21]. The authors categorized the subgingival microbiota organisms into groups, or complexes, according to their correlation with different illness severity and states of health (Figure 2). Specific bacterial complexes were linked to periodontal illnesses based on color designations. The complexes of blue, yellow, green, and purple indicate the early settlers of the subgingival flora. Complexes with orange and red hues indicate late settlers connected to fully developed subgingival plaque. Health and illness are linked to specific bacterial combinations. For instance, there is a higher likelihood that the bacteria in the red complex will be linked to clinical signs of periodontal disease, such as pocketing and clinical attachment loss[22–24].

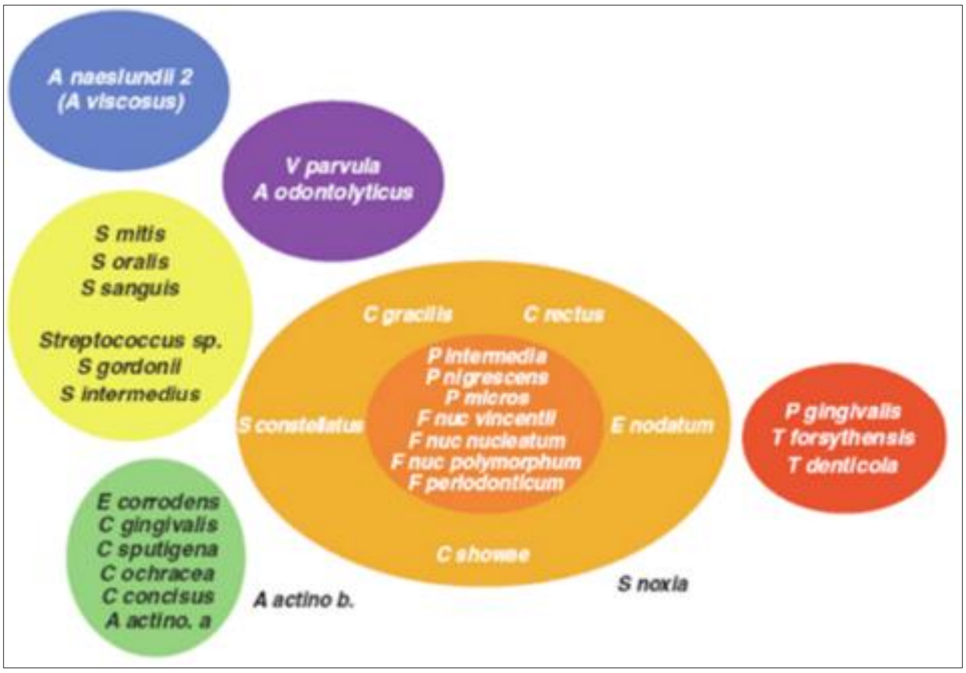

Figure 2 Subgingival biofilm microbiological complexes[21]

Comparing surface-bound microbes to their planktonic counterparts, they have a survival and/or selective advantage. Planktonic bacteria are less resistant to antimicrobial agents than the bacteria found in tooth plaque. Extracellular polysaccharides found in bacteria function as a barrier to shield the bacteria on plaque from external hazards such surfactants, antibiotics, antibodies, bacteriophages, and white blood cells. These polysaccharides also hinder the perfusion of antimicrobial drugs to bacterial targets. Antimicrobial agent resistance in biofilm bacteria is another possibility. Because of this, the minimum inhibitory concentration of antimicrobial drugs against bacteria in biofilm is much higher than that in liquid, often up to 1000 times higher[15, 22].

Saliva and bacterial surface adhesins, sucrose presence, mechanisms of low pH tolerance, carbohydrate metabolism, nitrogen metabolism, oxygen metabolism, production of intracellular and extracellular polysaccharides, and protease are among the factors that Krzysciak et al. described as influencing the formation of biofilm[25]. Another important aspect influencing the formation of the biofilm is the interactions between the bacteria in the oral cavity microbiome. This process can be sped up or slowed down by the interactions that take place between the microorganisms. In this sense, the pathogenicity of *S. mutans* is dependent on both the makeup of its bacterial flora and the oral cavity's environmental factors. The occurrence of *S. mutans* bacteria on dental surfaces is typically associated with inadequate personal hygiene and nutrition. These bacteria live in the hard tissues of the oral cavity, but they also inhabit soft tissues, which makes it easy for them to enter the oral cavity during kissing or when sharing personal care items. Additionally, it seems that eating frequently and keeping the oral cavity dehydrated may encourage colonization and the infection that follows. Without the use of disinfectants, irrigation alone could potentially be the source of colonization[26, 27].

In order to assess changes in orthodontic patients' dental plaque, Balenseifen et al. looked at pH, carbohydrate content, and the microbial populations of lactobacilli and streptococci[28]. Twelve patients from Loyola University School of Dentistry's orthodontic clinic, ranging in age from 10 to 16, were the research participants represented in the samples. One week prior to the teeth being banded, measurements were taken and plaque samples were collected. Four to five weeks after the teeth's bands and arch wires were affixed, another round of plaque samples was taken. Streptococci and lactobacilli, the two most common species in dental biofilm, showed noticeably higher values. The lactobacilli count increased dramatically, as prior salivary tests had indicated. There was a 9.8×10^4 rise in the mean lactobacilli count per milligram of plaque. The greatest aerobic component of the plaque, the streptococci, increased to 1.51×10^{14} bacteria/mg of plaque, indicating that they remained a significant element of the microflora. The colonial morphology on Mitis-Salivarius agar was utilized to further break down the streptococci into a S mitis and S salivarius count. Ultimately, following the installation of the orthodontic appliances, the plaque had a mean pH decrease of 0.4 units, an increase of 0.01 mg of glucose per milligram, an increase of 9.8×10^4 lactobacilli per milligram, and an increase of 1.5×10^{14} streptococci per milligram. *S. salivarius* types increased by 1.8×10^{10} and *S. mitis* by 1.5×10^{14}, accounting for the two different halves of the streptococci rise. The statistical comparison and analysis of these observations was done to determine the consequences for dental health[1, 9, 11, 29].

3. Self-Ligating and Elastomeric Metallic Brackets

The instruments used in orthodontic therapy to align and straighten teeth are called orthodontic brackets. It aids in malocclusion correction, dental health promotion, and pleasing appearance. Angle invented the fixed multi-banded edgewise orthodontic appliance in 1928. It consisted of a rectangular labial arch wire inserted into tubes or brackets fastened on bands that were bonded to specific teeth[30]. Figure 3(a) depicts the initial edgewise bracket that Angle introduced, which was a single, narrow bracket with a single set of tie-wings. In order to address the inadequacy of a solitary bracket in regulating the rotation and tipping of a tooth, the Lewis bracket was presented in Figure 3(b). Subsequently, Swain introduced a double-width bracket featuring two sets of tie-wings, known as the Siamese bracket (now called the twin bracket), which improved both rotational control and root position in the mesiodistal direction (Figure 3(c). As many types of braces have evolved, the classic metallic bracket usually consists of a base, slot or slots, and wings, as Figure 4 illustrates[29, 31].

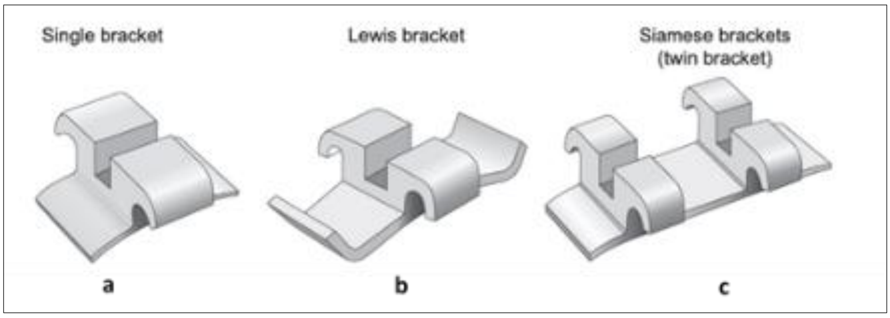

Figure 3 Illustrations of single bracket, Lewis bracket, and twin bracket

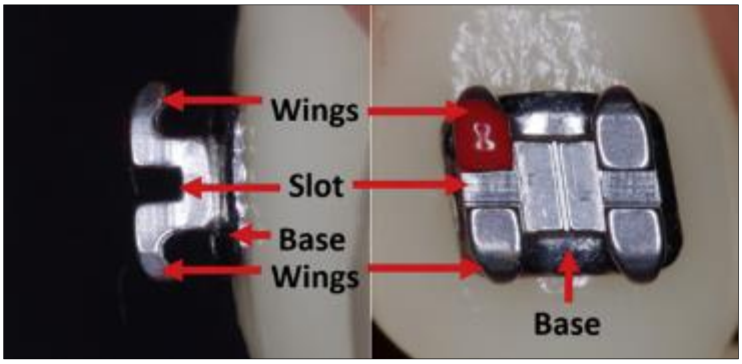

Figure 4 Figures of a bracket that display the wings, base, and slot[29]

3.1. Elastomeric metallic brackets

In orthodontics, tooth movement is accomplished by engaging the arch wire into the bracket slot using a robust tie ligature. For this purpose, ligatures made of metal or elastomeric materials are typically utilized (Figure 5). A significant amount of fixed orthodontic equipment store the forces that move teeth in the arch wire; in order for this force to be transferred to a tooth, the wires must be connected in some way to the bracket. To provide stiffness, twisted ends of stainless steel alloy wires with varied gauges (.009 to.014 inches) are folded back under the arch wire[31].

The bracket/arch wire junction is affected differently by steel ligatures according on how tight they are. Steel ligatures have the advantages of maintaining their strength and form while withstanding deterioration in the oral environment. They are also simpler to clean than elastomeric ligatures and offer less retention of bacterial plaque [32]. Steel ligatures have the disadvantage of requiring a lot of time and effort from the operator[32, 33]. According to research by Pinto et al., Shenoi et al., and Ai et al., using wire ligatures increased the time required to remove and replace two arch wires by about 12 minutes. They also need to be carefully tucked in at the ends to prevent soft tissue damage, but even then, they periodically come loose in between visits and hurt[34–36].

Elasticomeric ligatures provide an additional means of engaging the arch wire. It is a less strong alternative to metal ligatures that is more patient-friendly, comes in a variety of colors, and is simpler to apply[31]. Until the patient's subsequent appointment with the orthodontist, the elastomeric ligature is left in place[32, 35]. Complete arch wire engagement cannot be obtained or maintained by conventional ligation using elastomeric. Furthermore, they might make it more difficult to maintain proper dental hygiene, which is a novel orthodontic scenario. Furthermore, elastomeric ligatures have unsatisfactory physical characteristics. Elastic ligaments permanently change shape, which causes their force to diminish over time. The elastomeric material's force decay under continuous force application revealed that the most force degradation happened over a few hours[37, 38]. Furthermore, they quickly become permanently stained after being inserted into the oral cavity. More importantly, it has been demonstrated that elastomeric ligatures raise friction in sliding mechanic systems and 50–175 g more movement resistance in bracket/archwire systems[32, 36–38].

Figure 5 Elastomeric ligature (A), metal ligature (B)[31]

3.2. Self-ligating metallic brackets

The principle of self-ligation is as old as the edgewise bracket, according to Harradine, who introduced the first version of self-ligating brackets several decades ago. Nevertheless, the production and distribution of self-ligating appliances with active or passive ligation modes have increased within the last 20 years[8, 10, 38]. Self-ligating bracket systems are ligatureless bracket systems with an integrated mechanical component that seals the edgewise groove. The cap takes the place of the steel/elastomeric ligature and secures the archwire in the bracket slot. The self-ligating brackets transform the slot into a tube by means of the bracket's movable fourth wall[10, 38].

Self-ligating brackets can be classified into two primary groups based on how they close: active and passive. In order to rotate and manage torque, active self-ligating brackets have a spring clip that stores energy to press on the arch wire. Conversely, a slide that can be closed on passive self-ligating brackets typically does not encroach on the slot lumen, meaning that the arch wire is not actively forced (Fig. 6).[17]

a b

Figure 6 Passive vs. active self-ligating brackets (a), Passive self-ligating brackets (b)

4. Development of Bacterial Biofilms on Self-Ligating Versus Elastomeric Metal Brackets

The retention of dental biofilm is favored when brackets are used during orthodontic therapy. Changes in oral pH, the onset of caries, gingivitis, and periodontitis are the resultant conditions that the patient faces[14, 20]. The levels of lactobacilli and Streptococcus mutans in saliva and dental plaque were shown to be retained following therapy, according to studies by Balenseifen et al.[28] and Longoni et al.[8].

Comparing metallic ligatures with traditional brackets, the elastomer's deterioration may facilitate the growth of biofilm[9]. In order to address this issue, innovative techniques and materials were used to create orthodontic appliances, such as self-ligating brackets, which hold the orthodontic wire in place without the need for metallic or elastic ligatures[10].

The literature suggests that one of the best things about using self-ligating brackets is that it eliminates the need for metallic and elastomeric ligature wires. With this treatment, there are two main benefits: patients' oral hygiene improves and cross-contamination, which could happen accidently during ligature installation, is eliminated. The reason for the latter benefit is that the bracket surface would be easier to clean if the ligature were absent[32, 35]. The many add-on parts of fixed orthodontic appliances play a part in shifting the balance of the oral ecosystem. It's been demonstrated that having brackets and ligatures increases the risk of tooth surface decalcification, which eventually leads to the development of caries and white spots on teeth. It also increases gingival irritation [9, 10, 39].

Different findings on biofilm formation and microbe adherence for both conventional and self-ligating brackets have been published in numerous papers over the years. Different systems measure biofilm adhesion on brackets, which makes it difficult to assess the quality of the research[6, 40]. Comparing the plaque bacteria around two types of brackets—self-ligating (SL) and elastomeric metal brackets (E)—was the goal of a study done by Pellegrini et al.[41] (Figure 7). Ages ranged from 11 to 17 for the research participants in the samples. In 14 maxillary and 12 mandibular arches, they were bonded utilizing a split-mouth design with SL and E brackets, respectively. One and five weeks following bonding, recall visits were scheduled. In order to determine ATP-driven bioluminescence, plaque specimens were exposed to an assay based on luciferin and examined for oral bacteria. Dental bonded SL bracket teeth had lower levels of germs in their plaque than dental bonded E bracket teeth in the majority of cases. The means of oral streptococci and total bacteria at 1 and 5 weeks post-bonding were significantly lower in SL brackets compared to E brackets (P <0.05). Correlation coefficients of 0.895 and 0.843, respectively, showed a statistical relationship between the values of ATP bioluminescence and oral streptococci and total bacteria. In summary, the study found that SL brackets may minimize oral bacterial retention and that ATP bioluminescence may be a helpful technique for quickly measuring the amount of bacteria present in the mouth and evaluating oral hygiene during orthodontic therapy[7, 29, 42].

Figure 7 Self-ligating and elastomeric metal brackets: an experimental design and description, experimental design on maxillary arch (A); Self-ligating bracket, Innovation-R (B); Traditional elastomeric bracket, Mini-Ovation (C)

Longoni et al.[8] carried out a systematic review to examine the microbiological level of S. mutans retention around two different types of metallic brackets: self-ligating and conventional. For every one of the following electronic databases, a different search strategy was used: Google Scholar, LILACS, PubMed, SciELO, Science Direct, and Scopus. A search was conducted for more literature on Open Grey, including any that might have been overlooked. Every search was carried out on 2016- 2023. Five papers were included in the final qualitative systematic synthesis after a thorough screening process. Depending on the type, bracket systems are linked to bacterial buildup based on the facts and findings shown. Biofilm buildup in self-ligating brackets is generally lower (particularly when *S. mutans* is involved) [9, 10, 42].

However, a systematic evaluation with the same objective goal was out by Nascimento et al. [10] found no evidence to support a potential impact of the bracket design (traditional or self-ligating) on *S. mutans* colony formation and adhesion. They searched pertinent studies published between January 1965 and December 2012 using four databases: the Cochrane Central Register of Controlled Trials, Ovid ALL EMB Reviews, PubMed, and BIREME. After removing irrelevant criteria, the search technique produced 1,401 papers. Six of these articles were appropriate for the final analysis because they assessed clinical and periodontal factors resulting from bacterial adhesion in patients with C and SL brackets. Within the confines of this investigation, it was determined that there is no proof that the kind of bracket—conventional or self-ligating—has any bearing on the development of *S. mutans* colonies or their adherence [8, 27, 43, 44].

Remarkably, self-ligating brackets were found to have higher bacterial accumulation when compared to traditional brackets, according to research by Feres et al. [9]. Ten (n=10) of the traditional type and forty (n=40) of the self-ligating type from four distinct commercial brands comprised the fifty brackets that were examined. The brackets were separated into five groups, which were further explained as follows: 3M Unitek (Smart Clip, Monrovia, CA, USA), Aditek (Easy Clip, Cravinhos, SP, Brazil), Ormco (Damon System, Orange, CA, USA), and conventional (Morelli, Sorocaba, SP, Brazil) (Figure.8).

21 days had passed since bonding, at which point the plaque attached to the bracket bases' winglet, channel, and cervical areas was removed. After being diluted, the obtained materials were seeded into Mitis salivarius media specifically designed for S. mutans and an unspecified BHI culture medium on Petri dishes. After incubation for 24, 48, and 72 hours, colony forming unit (CFU) counts were done visually. The conventional brackets outperformed the self-ligating type in every examined region in terms of hygiene. The findings of Pithon et al's study are distinct from those of previous studies in the literature, according to them. Using both traditional and self-ligating brackets, Al Haifi et al. counted *S. mutans* in patient saliva and found no statistically significant changes. The variations between Pandis' study and the current

inquiry may result from different methodologies; in their work, CFU were counted in saliva rather than on bracket surfaces, as the current study suggests [33].

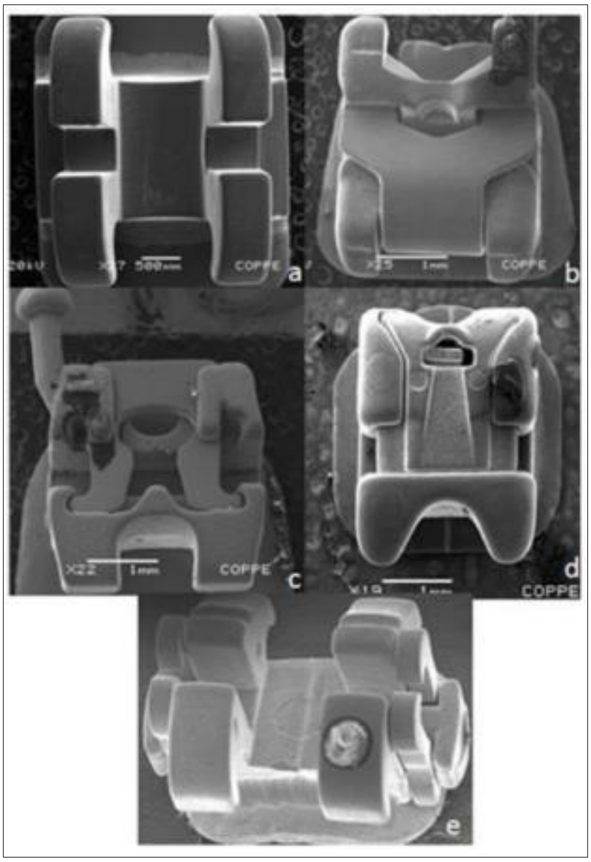

Figure 8 Brackets evaluated: Conventional (a); GAC (b); Aditek (c); Ormco (d); and 3M (e).

Figure 9 Intraoral frontal view of one of the patients, in whom brackets were bonded (a). Right side view (brackets used for bacterial plaque collection) (b). Left side view (brackets used for SEM evaluation) (c).

5. Conclusion

The results of numerous studies and articles using various methodologies have been published on the development of biofilms and microbe adherence for both conventional and self-ligating brackets. Each of these approaches for fastening the wire to the brackets has pros and cons; however, in terms of biofilm buildup, some research indicates that elastomeric ligatures are more likely to retain biofilm than the other two ligature methods. One study found that self-ligating brackets with bracket channels caused more bacterial biofilm accumulation than elastomeric brackets, while another found no discernible differences between the two types of brackets (elastomeric vs. self-ligating). Due to a lack of scientific data, orthodontists' decision to switch from elastomeric brackets to self-ligating brackets in their clinical practice in an effort to improve hygiene and reduce plaque accumulation cannot yet be implemented. Owing to the limitations of certain studies, more research on other bracket types—such as aesthetically pleasing self-ligating brackets—is required in order to visualize the periodontal complications that result from the various sizes, shapes, and materials of brackets. This research will also help to guide the development of new bracket design systems that minimize the accumulation of bacterial biofilm.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest to declare.

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