International Journal Dental and Medical Sciences Research
Volume 3, Issue 1, Jan-Feb 2021 pp 737-743 www.ijdmsrjournal.com ISSN: 2582-6018

Influence of Clear Retainers on Biofilm Accumulation in the Oral Cavity

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Submitted: 15-01-2021 Revised: 27-01-2021 Accepted: 31-01-2021

ABSTRACT: Background:Periodontal health in orthodontics has always been an area of controversy. Some have considered orthodontics to be an adjunctive part of treatment, whereas others, a precipitating factor of the disease. It is accepted that there is a transient increase in clinical signs of periodontal disease during orthodontic treatment, but it does not reach a threshold significant enough whereby disease progression can occur. Many studies have been carried out over the years to try and resolve this uncertainty. Studies have covered fixed and removable orthodontic treatment and its effects, as well as numerous studies on fixed and removable retainers and their consequences on periodontal health. However, few have concentrated on clear retainers.

Objective: The aim of this paper is to review the literature on the impact of clear retainers on biofilm accumulation related to periodontal health in order to add to the body of evidence on this topic.

Materials and methods:A systematic search of the medical literature produced between 1946 and 15th July 2020 was performed to identify all peer-reviewed papers on periodontal effects of clear retainers.

Results:608 articles were found from the initial search. Only 2 articles were found that described periodontal outcomes of removable retainers post fixed orthodontic treatment.

Conclusions: Clear retainersmay expose patients to further periodontal risk due to biofilm accumulation on the clear retainers.

Keywords: Clear, retainers, biofilm, periodontal, orthodontic, retention

I. BACKGROUND

Retainers are oral appliances that are fitted on or over teeth at the end of orthodontic (brace) treatment to prevent teeth from relapsing. Relapse is defined by the British Standards Institute (glossary of dental terms) in 1983 [1] as "The return, following correction, of the original features of the malocclusion." But can also be defined as "unfavourable change (s) from the final tooth position at the end of orthodontic treatment" [2].

Providing retainers is considered as the final phase of the orthodontic management. There are various types of retainers which are usually grouped into 'fixed' or 'removable'. The choice of retainer depends on different factors including [3, 4]: pre-treatment malocclusion, treatment mechanics, oral hygiene, periodontal health, residual growth, patient compliance, ease of fabrication, retainer durability and cost effectiveness.

Removable retainers are made of acrylic or a thermoplastic and are not fixed in the mouth. The two most common removable retainers are the 'Hawley' retainer (HR) and the 'clear retainer' (CR). CRs are also referred to in the literature as; 'vacuum formed retainer', 'Essix retainer', 'thermoplastic retainer', 'invisible retainer' and 'pressure formed retainer'[4, 5]. They wrap around the teeth and usually 2-4mm of the gingivae.

CRs are the most popular choice for retainers for orthodontists in the United Kingdom, Australasia and some parts of Europe due to their cost effectiveness. Their popularity ranges from 63% to 75% of all retainer types at all levels of care (private practice to government hospital settings) [6-8]. Advantages of CRs are [7, 9, 10] that they can be aesthetically and functionally acceptable, allow for good oral hygiene practices and are cost-effective [11]. They can be easily fabricated and fitted as well as be used for minor tooth movements or bleaching after the active orthodontic appliances (braces) have been removed.

Their disadvantages include patient reliance. Retainers may be misplaced or lost leading to relapse. They have poor wear resistance leading to more frequent replacement. CRs are unable to maintain expansion of the dental arches

International Journal Dental and Medical Sciences Research
Volume 3, Issue 1, Jan-Feb 2021 pp 737-743 www.ijdmsrjournal.com ISSN: 2582-6018

and can inhibit vertical settling[12](teeth touching opposing teeth). If the patient is not following oral hygiene instructions, enamel demineralisation and gingivitis are possible due to increased plaque retention.

II. MATERIALS AND METHODS

A systematic search of the medical literature produced between 1946 and 15th July 2020 was performed to identify all peer-reviewed papers periodontal effects of CRs. The search strategy is illustrated in Table 1. The following databases were searched: Embase, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R).

Further mapping and hand-searching was undertaken but the articles did not meet the inclusion criteria. 608 articles were found from the initial search. From this only 40 articles had relevant titles relating to the topic at hand. Further screening of abstracts of these 40 articles revealed only 2 articles that described periodontal outcomes of removable retainers post fixed orthodontic treatment. Unfortunately, the 2 remaining articles did not investigate full coverage CORs and had to be excluded as well leaving 0 articles which had researched immunological response of the host's oral cavity to the COR biofilm.

Table I)Search Strategy

#	Search strategy	# of results
1	Microbi	1136692
2	Biofilm	42941
3	Plaque	109742
4	Immuno	3121949
5	Perio	1944221
6	Biomarker	130453
7	(antimicrobial and peptides)	22889
8	Peptides	442059
9	"gingival crevicular fluid"	3975
10	Saliva	61133
11	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10	6234533
12	Limit #11 to English language	5592865
13	Orthodonti	57426
14	Retainer	1393
15	Removable	16488
16	#14 OR #15	17617
17	#13 AND #16	4221
18	#12 AND #17	610
19	Remove duplicates from #18	608

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III. RESULTS

Material Properties of Clear Retainers

CRs provide a surface and environment that permits biofilms to form free from host immune factors [13]. Furthermore, with full occlusal coverage, CR wear may impede the natural buffering capacity by saliva and render the teeth more susceptible to cariogenic bacteria [14]. Micro-abrasions and irregularities on the CR surface may promote bacterial colonization and formation of biofilms [15].

Fabrication of CRs can be done in two ways:[4, 16]

- positive pressure machines,which force the heat softened thermoplastic material over the final plaster model or
- vacuum machines, that use negative pressure to adapt the thermoplastic to the final plaster model.

The materials used are mainly of two types: [4, 16]

- Co-polyester/ polyethylene polymers (Essix 'A', Endure, Erkodur, TR)- which is said to be more aesthetic and less durable, but allows acrylic to be bonded to it.
- Polypropylene / ethylenecopolymer (Essix C+, Invisacryl C, Duraforce)- which is said to be less aesthetically pleasing but more retentive and flexible.

A combined version is now available to attain the best of both material subtypes (ACE, Dura-transparent) [17]. Recently, a new material has been advocated for use as a CR [18]. This is a triple layer hybrid thermoplastic. They report that the layers do not delaminate and that the material has good wear resistance and decreased water absorption rate compared with other designs.

Material properties' effects on biofilm

Alcohol, water and plaque microorganisms can affect the durability of these retainers as they can cause plasticising and leaching through degradation of the polymers [18]. The composition of the biofilm has been shown to be variable also, depending on the chemical compositions and physical characteristics of the CR material and saliva [14, 15, 19-21].

Surface texture also seems to affect only the number of bacteria in the biofilm, but not the species. A rough surface increases the surface area available for colonization and also shelters the bacteria. A minimum surface roughness of Ra = 0.2 µm has been suggested as a threshold value for bacterial retention. Below this value, no further reductions were observed, while over this value, biofilm accumulation increased with increasing roughness [22].

Surfaces with a low surface energy usually display lower adherence to biofilms than similar surfaces with higher surface energy. Most dental materials, with the exception of ceramics, have a higher surface energy than enamel and have thus a greater risk of biofilm accumulation. It is difficult to distinguish between surface roughness and surface energy, but it is thought the former is a bigger factor. The chemical composition of the dental material will further affect the bacterial adhesion due to the material-protein interactions.

Schweikl et al [23] analysed different dental materials to calculate the correlation between hydrophilicity and hydrophobicity of a material surface, protein adsorption, and bacterial adhesion. They found the surface roughness of polyethene (PE) was 0.53 µm compared to Groosh et al who found the Essix ACE (a similar material to PE) to be 0.37±0.30 µm. The study showed that even though PE had a highly hydrophobic surface, the water contact angles interestingly remained unchanged after protein coating as the highest amount of salivary proteins adsorbed to the most hydrophobic surfaces. They concluded that adhesion of S. gordonii DL1 to smooth surfaces of various dental biomaterials revealed a negative correlation between the hydrophobicity of pure surfaces and the number of attached microorganisms. This reinforces the host response and original environmental constituents being a major factor in determining the composition and build-up of the microbial community with appliances such as CRs.

Biofilm accumulation on clear retainers

Only 4 studies have looked at microbiota associated with CRs [14, 15, 24, 25]. CRs, like any other (intraoral) prostheses, are associated with an increase in biofilm accumulation i.e. plaque [26, 27] and can therefore lead to infection.

Turkoz et al [14] tested if CRs influenced the oral microbial flora with respect to S. mutans and Lactobacillus, as CRs were thought to prevent the 'flushing' effect of saliva on oral tissues. The patients had recently completed fixed orthodontic treatment and were now wearing CRs. The study showed that there was a statistically significant increase in Lactobacillus with 2 months wear of the retainer compared to the levels prior to the retention stage.They concluded that CRs have a positive effect on the colonisation of oral microbiota on dental surfaces and recommended extra oral hygiene and dental care in patients wearing CRs. This study therefore, confirms that CRs have a similar effect to other orthodontic appliances and increase bacterial counts. However,

International Journal Dental and Medical Sciences Research
Volume 3, Issue 1, Jan-Feb 2021 pp 737-743 www.ijdmsrjournal.com ISSN: 2582-6018

the above appliances were worn full time and CRs can now be worn mostly on a part time basis. This along with good oral hygiene practices of the oral cavity and of the CR, would remove the early colonisers preventing further proliferation of the biofilm and helping the host response to challenge any pathogenic challenge.

Low et al [15] investigated the features and distribution of biofilms on Invisalign orthodontic appliances in 'slow' and 'fast' plaque former patients. They found colonisation to be quicker and more abundant in the fast plaque forming group. However, in the later stages of biofilm formation, both groups showed no difference in surface biofilms, although the fast group had a more complex structure. The recessed areas of the appliance harboured more biofilm compared to flat surfaces.

Al Groosh et al [24] found that more than 50% of the 101 orthodontic Hawley and Essix type retainers harboured non-oral opportunistic pathogens. 66.7% of the retainers had Staphylococcus spp. (including Methicillin Resistant Staphylococcus aureus (MRSA)) and 41.6% had Candida spp. However, the viable counts were lower with 8% Staphylococcus and 0.13% of the total count on the removable appliances. But the same species were not found in any of the non-retainer wearing individuals. This is thought to be because the oral environment is changed by wearing CRs, leading to changes in the biofilm of orthodontic retainer wearers. The authors concluded that these retainers can be a reservoir for opportunistic pathogens including MRSA and can act as a source of cross infection that can have an adverse effect on patients' health.

Manzon et al[25] found that CRs may be more susceptible to biofilm colonization compared to HRs.CRs may favour bacterial adhesion because ofconcavities,and abrasion that can increase surface roughness. Due to the number of concavities, it is more difficult to clean the retainer to control the biofilm formation. Plaque and tartar were found to be more continuous on CRs, but for HRs, plaque and tartar weresmaller, discontinuous and located mainly onlingual surfaces.

In this study, after 3 months the subjectsswitched from full-time wear to night-time only. This may have contributed to normalizing the periodontal and gingival health indexes. They also found that reducing daily weartime may have decreased the incidence of dental health problems in the CR group, leading tocomparable outcomes with the HR group.

IV. DISCUSSION

Implications of Biofilm Accumulation in the Oral Cavity

Biofilms provide protection and nutrients for 'opportunistic' microbes and can be attributed as the causative factor for up to 65% of all clinical pathological infections, including oral infections such as caries, periodontal disease, endodontic infection, and mucosal infections [15, 28]. Because the heterogeneous microorganisms in a biofilm are encased in the extracellular matrix, they can become highly recalcitrant to host and therapeutic factors and therefore can have devastating consequences [29] by tipping the balance of inflammation in favour of the pathogenic microbes.

Changes in the oral environment lead to the modification of the bacterial communities present in dental plaque. Substances released from plaque such as lipopolysaccharides (LPS), antigens and other virulence factors, gain access to the gingival tissue and initiate an inflammatory and immune response through activation of host defence cells [30]. It is accepted that periodontitis is associated with specific bacterial species and polymicrobial colonisation of the teeth surfaces; however, the amount of bacterial plaque per se does not completely explain the clinical and pathological features of periodontitis [31]. Although gingivitis and chronic periodontitis are initiated and sustained by bacterial plaque, the host defence mechanisms are believed to play an important role in their pathogenesis [32].

Host Immune Response and Periodontal Disease

The host immune response is important in maintaining the health of periodontal tissues. The presence of pathogens in periodontal pockets will activate innate and adaptive immune responses [33]. Continuous activation of the immune responses will cause inappropriate inflammation indirectly leading to periodontal tissue destruction [34] through inflammatory mediators including cytokines, chemokines, arachidonic acid metabolites and proteolytic enzymes. The interaction between the host, innate, inflammatory, and adaptive immune responses and periodontopathogens is crucial to the pathogenesis of periodontitis [30, 35].

These processes and interactions occur naturally in healthy mouths as a protective feature and are not detectable at the clinical level. But a shift in the plaque biofilm microbiota can lead to an increasingly active pro-inflammatory cytokine response in the peridontium. That is, bacteria initiate disease, but the key destructive events in periodontitis are caused by host derived mediators

and enzymes released by inflammatory cells (and can almost be considered as 'collateral' damage resulting from the inflammatory response) in a susceptible host.

The most recent Cochrane review on retainers [36] only found one study analysing the adverse effects on oral health [37] from the 15 studies they included in their qualitative synthesis. This randomised controlled trial compared bonded retainers (BRs) against CRs at debond (T1) and 12 months post debond (T2). The CRs were worn full-time for the 12 months except at mealtimes. They measured caries, gingival bleeding and periodontal pocketing (>3mm) were recorded for the lower six anterior teeth. They found that there was significantly more gingival bleeding in the BR group than the CR group. They also found that there was more periodontal pocketing in the bonded retainer group. However, this periodontal pocketing result should be viewed with caution as the two groups were not equal. The authors of the trial therefore concluded that periodontal pocketing is similar between fixed retainers and CRs but fixed retainers are associated with poorer gingival health. The design of the study was good but there may have been some bias in reporting the outcomes.

As experts have now advocated that retainers be worn indefinitely (on a nightly basis) this may expose the patient to further periodontal risks due to build-up of biofilms on the CRs over time. If this is the case, then one could assume that the same disease processes and host responses would occur from wearing a CR indefinitely.

V. CONCLUSIONS

- Material properties of CRs such as their surface texture, roughness, energy and thicknesscan affect the biofilm.
- CRs increase the colonisation of oral microbiota on dental surfaces and can be a reservoir for opportunistic pathogens, acting as a source of cross infection that can have an adverse effect on patients' health.
- Retainers are now advised to be worn indefinitely which may expose patients to further periodontal risk due to biofilm accumulation on the CRs.

Abbreviations

- Clear retainer = CR
- Hawley retainer = HR
- Bonded retainer = BR
- Polyethene = PE
- Methicillin Resistant Staphylococcus aureus = MRSA

Declarations

- Ethics approval and consent to participate: Not applicable.
- Consent for publication: Not applicable.
- Availability of data and material: Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.
- Competing interests: The authors declare that they have no competing interests.
- Funding: No sources of funding to declare.
- Authors' contributions: HAB carried out the literature search and reviewed the articles. HQ responsible for manuscript drafting and revision. All authors read and approved the final manuscript.
- Acknowledgements: Not applicable.

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