Review Article

Physical Effects of Cleaning Agents on Orthodontic Thermoplastic Retainer Polymer: A Narrative Review

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Abstract

Aim: Orthodontic thermoplastic retainers are fabricated from polymers such as polyurethane, copolyester, polypropylene, and modified polyethylene terephthalate glycol (PET-G). This review outlines the cleaning methods employed by clinicians and patients and discusses the evidence related to the effect on the physical properties, including translucency, surface roughness, flexibility, and color of the thermoplastic polymer material. **Materials and Methods:** An electronic search through Web of Science, Scopus, Google Scholar, and PubMed was performed, seeking original studies published between January 2010 and July 2021 on cleaning agents' effect on thermoplastic retainers' physical properties. There were only six *in-vitro* studies found and they investigated 14 cleaning agents on the 4 most used polymer materials. There were no clinical studies carried out in this area of research. **Results:** PET-G was the polymer least impacted by cleaners. Its structural integrity was not altered much by Invisalign Cleaning Crystals, Retainer Brite, Cetron Powder, Corega tablets, or brushing with toothpaste. Polyurethane and copolyester retainer polymer experienced the least notable changes when cleaned with Invisalign crystals or Retainer Brite. Dawn dish soap was the only cleaning agent that caused little changes in the polypropylene polymer. Generally, it may be best to avoid cleaning retainers made of polyurethane, polypropylene, and copolyester with vinegar or hydrogen peroxide. **Conclusion:** This narrative review has summarized the commonly used cleaning agents' effects on the physical properties of thermoplastic polymer. Further trials are needed to offer the best retainer cleaning agent with least adverse effects on the physical properties of the retainer polymer.

Keywords: Orthodontic Retainer Polymer Material, Retainer Cleaning Agent, Retainer Material, Retainer Material Properties, Thermoplastic Retainer

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Introduction

Orthodontic retention is defined as the holding of teeth in the treated position following orthodontic treatment to maintain the result.[1] A popular form of orthodontic retainer is the thermoplastic retainer, a removable clear plastic retainer first described by Ponitz in 1971.[2] It is popular because of its clinical efficiency, cost-effectiveness, and patient acceptability.[2] Other advantages of thermoplastic retainers include their aesthetic features, ease of fabrication, and minimal adjustment requirements.[3] The indefinite retainer use is associated with the degradation and breakage of thermoplastic retainer.[4] Despite the advancement of retainer material to enhance the clinical success of the retention phase, loss of translucency, weakening of the material integrity, and discoloration may hinder patients' adherence to retainer wear. The retainer cleaning method is a topic that has not been fully explored but is crucial to ensuring orthodontic retainers' safe use.

As the post-orthodontic treatment retention period is indefinite, it is pertinent to have a proper retainer cleaning

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protocol to maintain the durability of the retainer. The British Orthodontic Society recommendation is to clean retainers daily using cold water and to avoid using toothpaste as it may roughen the retainers and change their color.[5] The American Association of Orthodontists recommends brushing the retainer with toothpaste twice a day or using a chemical cleaner. Standard protocols on cleaning thermoplastic retainers are still not available.[6] To consider the best cleaning methods, relevant studies that have assessed the effect of cleaning agents on thermoplastic retainers are discussed in this review.

The rationale for carrying out this narrative review was in view of the limited evidence on the physical effects of the cleaning agents on the popular orthodontic thermoplastic retainers. The limited published articles that were found were all laboratory-based studies. A systematic review was impossible as we could not segregate and select some articles as the total evidence was scarce. Hence, this review was narrative in nature, taking into consideration all the publications found between January 2010 and July 2021.

The objective of this review was to create awareness on the different polymer materials used for the fabrication and to summarize the possible physical effects on the polymer material that has been proven so far in the laboratory. Furthermore, the objective is also to encourage a clinical study to be carried out on the effects of the various cleaning agents on the thermoplastic retainer polymer.

Materials and Methods

Eligibility criteria

The Problem-Intervention-Comparison-Outcome-Study design (PICOS) framework was used to specify the study characteristics in the strategy to find the journals to be reviewed. We included all *in-vitro* trials of any methodological design. Excluded were non-physical reports, or studies without using any cleaning agents on thermoplastic retainers.

Information sources

An electronic search through Web of Science, Scopus, Google Scholar, and PubMed was performed, seeking original studies published between January 2010 and July 2021 on cleaning agents' effect on thermoplastic retainers' physical properties.

Search strategy

The following MeSH headings and keywords related to the studies were used: "retainer material," "thermoplastic retainer," "retainer cleaning agent," "retainer material properties," and "orthodontic retainer polymer material."

Study selection

Titles identified from the literature search were screened by one author (IA) with a subsequent duplicate independent checking of their abstracts/full texts against the eligibility criteria by a second author (SDS). PRISMA flow chart is in Figure 1. Inclusion and exclusion criteria are mentioned in Table 1.

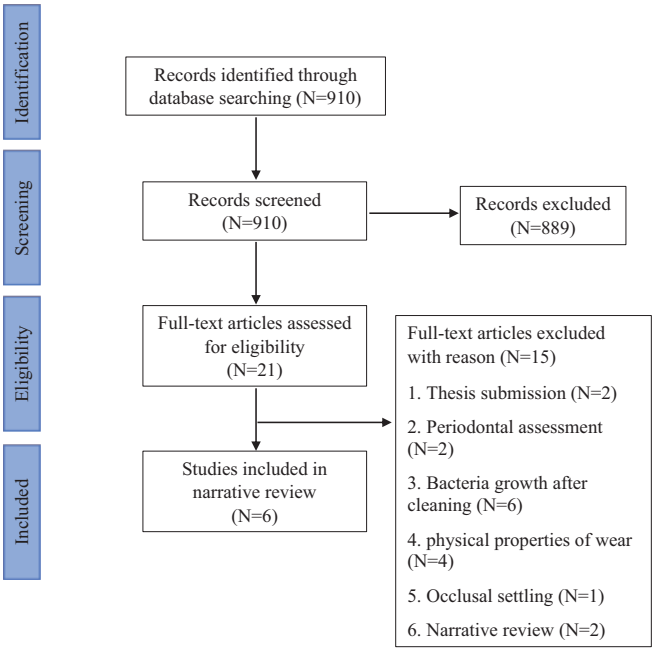

Figure 1: PRISMA flow chart

Table 1: Inclusion and exclusion criteria

Inclusion	Exclusion
• Observational and experimental studies on cleaning agents and orthodontic thermoplastic retainers • Mechanical, chemical, or a combination of all cleaning methods of orthodontic thermoplastic retainers	• General articles on thermoplastic retainer • Non-English articles • Case reports or thesis write-ups

Data collection process

Characteristics of included trials (research methodology, physical properties, and thermoplastic retainer polymer) were extracted independently by the author (IA). Missing or unclear information was requested by the trials' authors.

Results

The PICOS framework was defined as:

Problem—Physical effects of the cleaning agents on the popular orthodontic thermoplastic retainers
Interventions—Mechanical, chemical or a combination of all cleaning methods
Comparison—Any comparison group
Outcome—Cleaning agents' effect on thermoplastic retainers' physical properties
Study design—Observational and experimental studies

Table 2: Thermoplastic retainer product, polymer composition, and manufacture

Product	Composition	Manufacturer
Essix C+	Polypropylene	Dentsply Raintree Essix,
Invisacryl C	Polypropylene	Great Lakes Orthodontics
Essix ACE	Polyethylene terephthalate (copolyester)	Dentsply Raintree Essix,
TR	Polyethylene terephthalate-glycol (PET-G)	Bay Dental Direct
Duran		SCHEU-Dental GmbH
Tru-Tain		Tru-Tain Rochester
Vivera	Polyurethane	Align Technology Inc.

Characteristics and risk of bias of included studies

From the results of the electronic search using the above-mentioned PICOS framework in the eligibility criteria section, a total of six *in-vitro* studies were identified. No assumptions of simplifications were made in this narrative review. Polyurethane, copolyester, polypropylene, and modified polyethylene terephthalate glycol (PET-G) are the predominant thermoplastic materials used to fabricate orthodontic retainers.[7,8] The thermoplastic retainer products and their composition are listed in Table 2. To date, limited studies have evaluated the properties of orthodontic thermoplastic retainers.[9] A total of 774 thermoplastic retainer polymer samples were used. The studies were conducted over a duration of 7 days and up until 6 months. Table 3 contains the materials, methods, and findings of studies that have investigated the effects of cleaning methods on translucency, surface roughness, flexibility, and color changes of the retainer material.

The risk of bias analysis was not performed due to the limited data. Being a narrative review, the risk of bias is potentially high in the included studies.

Discussion

Types of retainer cleaning agent

Mechanical cleaning

Mechanical cleaning can be achieved by brushing the retainer with a toothbrush using water or an additional compound such as toothpaste. The use of a toothbrush is practical and can remove gross debris and plaque deposition. Patients are also advised to use an additional agent to improve the efficiency of retainer cleaning.[10] *In-vitro* evidence suggested that fluoridated toothpaste may be employed.[10] However, there are contradicting opinions on this matter. Some clinicians do not recommend using toothpaste because the abrasive component in the toothpaste may scratch the surface of the retainer, allowing further microorganism colonization. The presence of abrasive agents in toothpaste formulations can cause roughness on the surface of the thermoplastic retainer. To overcome this, manufacturers have formulated retainer paste such as Polident Paste, consisting of less abrasive formulations than regular toothpaste.

A combination of mechanical and chemical cleaning appears to be the most effective in reducing plaque and microbial counts.[11-14] Chemical agents enhance the remaining plaque and stain breakdown.[10]

Chemical cleaning agent

Chemical cleaning agents are available in the form of tablets, powders, or liquid solutions. Retainer Brite, Polident, Invisalign Cleaning Crystals (CC), and Corega are examples of commercial products available in the tablet form. While Corsodyl and Listerine mouthwashes are examples of chemical commercial cleaning liquids. These mouthwashes contain chlorhexidine gluconate, a potent antimicrobial agent that can quickly kill microorganisms. However, prolonged immersion of thermoplastic retainer in chlorhexidine gluconate may cause distortion and staining. Therefore, chlorhexidine-based liquids are not recommended for daily use.[10]

Home-based cleaning agent

A survey by Kılınç and Sayar[15] revealed that patients use a variety of readily available detergents such as dish soap, vinegar, and olive oil to clean thermoplastic retainers. These home products were found to be more practical and economical compared with commercial cleaning agents. However, there are no clear scientific reports on the compatibility and efficacy of these home-based products with the thermoplastic retainer.[16,17]

Effects of cleaning agents on thermoplastic retainer polymer

Effective cleaning methods can increase the life span of retainers and promote overall better retainer-wear compliance. Thermoplastic retainer is favored due to its aesthetic appearance. Hence, maintaining its translucency and color stability is a crucial concern. Repetitive cleaning may cause deterioration of its physical properties. Over time, the retainer will change in its translucency and color and deteriorate in its flexibility and surface texture. It is crucial to understand the potential adverse effects of cleaning methods to provide appropriate advice to orthodontic patients.[18] The cleaning agents in these studies were based on information gathered from clinicians and patients.

Polyurethane (Vivera, Invisalign, and Clear Correct)

Cleaning using Invisalign CC, Polident, and Listerine resulted in the least change in translucency, no effect on flexibility, and insignificant changes in surface roughness.[19] Furthermore, Invisalign CC and Retainer Brite were excellent at removing staining due to the compounds in tea.[20] Toothbrushing the retainer with

Table 3: Literature survey on thermoplastic retainer cleaning agents' effects on physical properties

No.	Study	Type of study	Thermoplastic retainer material	Sample size	Cleaning agent	Cleaning protocol	Duration	Primary outcome	Findings
1	Agarwal *et al.*, 2018	*In vitro*	Polyurethane (Vivera, Align Technology Inc.)	80	Group 1: Invisalign CC Group 2: Polident Group 3: Listerine Group 4: Vinegar Group 5: Sodium hypochlorite Group 6: Hydrogen peroxide Group 7: Toothbrushing with distilled water (DW)	Retainer material cleaned twice a week in designated cleaning solution following manufacturers' instructions or brushed with a toothbrushing machine	Six months	Flexural modulus, light transmittance, and surface roughness after exposure to different cleaning agents	Invisalign CC, Polident, and Listerine showed the least changes and therefore may be recommended
2	Wible *et al.*, 2019	*In vitro*	Copolyester (Essix ACE, Dentsply GAC)	80	Group 1: Invisalign CC Group 2: Polident Group 3: Listerine Group 4: Vinegar Group 5: Sodium hypochlorite Group 6: Hydrogen peroxide Group 7: Toothbrushing with DW Group 8: Retainer Brite				Invisalign CC and Retainer Brite may be used for cleaning twice a week; however, Listerine was not recommended
3	Wible *et al.*, 2019	*In vitro*	Polypropylene/ethylene copolymer (Essix C+, Dentsply GAC)	80					No ideal cleaning method was found
4	Kim *et al.*, 2018	*In vitro*	Ethylene vinyl acetate copolymer (Proform Soft EVA) and polypropylene/ethylene copolymer (Essix A+)	192	Group 1: Dawn dish soap Group 2: Listerine Group 3: Retainer Brite Group 4: TheraBreath mouth rinse	Positive control: Immersed in cleaning solutions for 16 h Method 2: Immersed in cleaning solutions for 15 min and bench dry for 16 h Method 3: Immersed in cleaning solutions for 15 min and immersed in DW for 16 h Negative control: Immersed in DW for 16 h	15 days	Surface roughness and hardness	Dawn dish soap is recommended
5	Bernard *et al.*, 2020	*In vitro*	Polyurethane (Invisalign, Align Technology, and Clear Correct, USA) and modified polyethylene terephthalate glycol (PET-G) Minor Tooth Movement, Dentsply Sirona	300	Group 1: Invisalign CC Group 2: Cordless Sonic Cleaner combined with a Retainer Brite	Retainer material soaked in five different coloring media daily for 7 days and cleaned for 15 min	Cleaned once after 7 days of immersion in staining solution	Stain-removal potential of commercial cleaning agents on the thermoplastic aligner materials	Invisalign Cleaning Crystals and Cordless Sonic Cleaner with Retainer Brite have excellent potential for removal of the staining compounds in tea
6	Porojan *et al.*, 2020	*In vitro*	Polyethylene terephthalate gylcol (PET-G) specimens Duran (Scheu-Dental GmbH), Biolon (Dreve Dentamid GmbH), and Crystal (Bio Art Dental Equipment)	42	Group 1: Centron Group 2: Corega Group 3: Electric toothbrush with Colgate toothpaste	Immersion in Cetron was 30 min, Corega tablets 3 min, and toothbrushing for 2 min	Samples cleaned every 24 h for 7 days	Optical and surface roughness changes	No significant differences were found between these methods

NA: not available

Table 4: Summary of cleaning agents' effects on physical properties of thermoplastic polymer

	Thermoplastic polymer Cleaning agents	Polyurethane (Vivera, Invisalign, and Clear Correct)	Copolyester (Essix ACE)	Polypropylene (Essix C+ and Essix A+)	PET-G (Duran, Biolon, Crystal, and Minor Tooth Movement)
1.	Invisalign Cleaning Crystals tablet	Roughness: insignificant[19] Translucency: least changed[19] Flexibility: insignificant Color: good[20]	Roughness: insignificant Translucency: insignificant Flexibility: insignificant[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significantly increased[22] Color: NA	Roughness: NA Translucency: NA Flexibility: NA Color: good[20]
2.	Polident tablet	Roughness: insignificant[19] Translucency: least changed[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: insignificant Flexibility: insignificant[21] Color: NA	Roughness: significant increased Translucency: significant decreased Flexibility: significant increase[22] Color: NA	NA
3.	Listerine mouthwash	Roughness: insignificant[19] Translucency: least changed[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: most decreased Flexibility: insignificant[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significant increase[22] Color: NA	NA
4.	Cordless Sonic Cleaner with Retainer Brite tablet	Roughness: NA Translucency: NA Flexibility: NA Color: excellent[20]	NA	NA	Roughness: NA Translucency: NA Flexibility: NA Color: good[20]
5.	Retainer Brite tablet	Roughness: insignificant Translucency: most decreased[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: insignificant Flexibility: none[21] Color: NA	Roughness: significant increase Translucency: insignificant Flexibility: none Color: NA	NA
6.	Dawn dish soap	NA	NA	Roughness: insignificant Translucency: significantly decreased[22] Flexibility: significant increase Color: NA	NA
7.	Cetron powder	NA	NA	NA	Roughness: insignificant Translucency: NA Flexibility: NA Color: good[23]
8.	Corega tablet	NA	NA	NA	Roughness: insignificant Translucency: NA Flexibility: NA Color: good[23]
9.	Colgate toothpaste	NA	NA	NA	Roughness: insignificant Translucency: NA Flexibility: NA Color: good[23]
10.	Brushing with distilled water	Roughness: insignificant Translucency: most decreased[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: most decrease Flexibility: insignificant[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significant increase[22] Color: NA	NA

Table 4: Continued

	Thermoplastic polymer Cleaning agents	Polyurethane (Vivera, Invisalign, and Clear Correct)	Copolyester (Essix ACE)	Polypropylene (Essix C+ and Essix A+)	PET-G (Duran, Biolon, Crystal, and Minor Tooth Movement)
11.	2.5% vinegar	Roughness: insignificant Translucency: most decrease[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: insignificant Flexibility: insignificant[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significant increase[22] Color: NA	NA
12.	0.6% sodium hypochlorite	Roughness: insignificant Translucency: most decrease[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: insignificant Flexibility: insignificant[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significant increase[22] Color: NA	NA
13.	Hydrogen peroxide	Roughness: insignificant Translucency: most decrease[19] Flexibility: insignificant Color: NA	Roughness: insignificant Translucency: insignificant Flexibility: significant decrease[21] Color: NA	Roughness: significant increase Translucency: significantly decreased Flexibility: significant increase[22] Color: NA	NA
14.	TheraBreath mouthwash	NA	NA	Roughness: significant increase[18] Translucency: NA Flexibility: NA Color: NA	NA

NA: not available

distilled water and vinegar demonstrated a decrease in translucency and flexibility, respectively.

Copolyester (Essix ACE)

Cleaning using Invisalign CC and Retainer Brite showed no effect on flexibility and insignificant surface roughness and translucency changes.[21] Although brushing with distilled water and Listerine appeared to affect the translucency the most, brushing and hydrogen peroxide affected flexibility the most.

Polypropylene (Essix A+ and Essix C+)

Dawn dish soap caused the least surface roughness and hardness changes but was not tested on translucency and color change.[18] While brushing with distilled water, Invisalign CC, Polident, Listerine, vinegar, sodium hypochlorite, hydrogen peroxide, and TheraBreath showed significant changes in surface roughness, flexibility, and translucency and therefore not recommended to be used.[18,22]

Polyethylene terephthalate-glycol or PET-G (Duran, Biolon, Crystal, and Minor Tooth Movement)

Cleaning using Cetron, Corega, Colgate, Invisalign CC, and Cordless Sonic Cleaner with Retainer Brite demonstrated an insignificant change in translucency and surface roughness and are excellent in removing tea stains.[20,23]

Summary of evidence

A summary of cleaning agents' effects on the physical properties of each thermoplastic polymer based on the six studies is presented in Table 4.

Surface roughness

The seven different cleaning agents did not cause significant differences in surface roughness in the polyurethane, copolyester, and polypropylene. The values were well below 0.5 μm as measured by the surface profilometer, implying that the changes in roughness found may not be clinically relevant.[19,21,22] Porojan *et al.*[23] found that cleaning PET-G with Cetron, Corega, and toothpaste for 7 days was insignificant. However, some clinicians have advised explicitly against cleaning thermoplastic retainer with toothpaste as this may scratch the surface of the retainer and lead to an increased surface area,[8] facilitating bacterial adherence and subsequent teeth demineralization.[23] Further trials are needed to evaluate this matter.

Translucency

Cleaning polyurethane retainer using Invisalign CC, Listerine, and Polident did not change the polymer

translucency.[19] Listerine reduced polyethylene, copolyester, and polypropylene translucency the most, rendering it to be unaesthetic.[21,22] Although Listerine or Corsodyl is often used as part of daily oral hygiene for its antibacterial properties, Listerine may indeed not be biocompatible as a cleaning agent for the retainer.

Flexibility

Out of the seven cleaning agents tested on polyurethane retainers, the flexibility of the retainer decreased the most when vinegar and toothpaste were used as cleaning agents.[19] Decreased flexibility means that the retainer becomes stiffer or harder. For the polypropylene retainers, most cleaning agents resulted in reduced flexibility. The cleaning agents had no significant effect on the flexibility of the PET-G retainer material. This may be due to PET-G having better dimensional stability, formability, optical qualities, and fatigue resistance.[7]

Color

No studies had investigated color changes of thermoplastic retainer after exposure to coloring media and cleaning agents. Bernard *et al.*[20] analyzed color changes of thermoplastic polyurethane and PET-G aligners. Considering that the structure of a thermoplastic retainer is similar to a thermoplastic aligner, this study provided insight into the two similar appliances. Thermoplastic retainers maintain the results of orthodontic treatment, whereas thermoplastic aligners exert active force to achieve orthodontic tooth movement as an alternative to a fixed appliance.[14] Two cleaning agents, the Invisalign CC and Retainer Brite, have excellent stain-removal potential, precisely the staining compounds in tea.[20]

Limitations

Only six *in-vitro* studies were electronically retrieved between January 2010 and July 2021. All six studies had used flat thermoplastic retainer material which did not mimic the contour of teeth as in real-life retainer.[19,21,22] As all these studies were *in-vitro* studies, the thermoplastic discs were not exposed to the oral cavity, including the oral bacteria, enzymes, and physiological functions, including speech and swallowing.[20] The cleaning agents in these studies were based on information gathered from clinicians and patients. The results from the studies were reliant on the methodology within individual studies. Comparison between different studies and materials may not be straightforward, and results should be interpreted with caution.[24] The studies were conducted in Western countries. Thus, the cleaning agents used may not be readily available in other countries and may require additional postage service, complicating retainer cleaning recommendations. This review can be resourceful in formulating a clinical study protocol in the future to add to the existing evidence of higher ranking.

Conclusion

Cleaning agents adversely affect each thermoplastic retainer polymer at various degrees. This review has summarized the commonly used cleaning agents' effects on the physical properties of four commonly used thermoplastic polymers, which are polyurethane, copolyester, polypropylene, and modified PET-G. Knowing the thermoplastic retainer polymer used in each clinical setting is pertinent to allow a clinician to advise the best cleaning agent to the patients with the least adverse effects on the retainer properties. Further studies that include additional materials, cleaning methods, and cost-effectiveness must be carried out.[23]

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Conflicts of interest

There are no conflicts of interest.

Authors' contribution

Study conception (SDS), data collection (IA), data acquisition and analysis (SDS, NMNM, HBSGK, IA), data interpretation (SDS, NMNM, IA), manuscript writing (SDS, IA, NMNM).

Ethical policy and Institutional Review Board statement

Not applicable.

Patient declaration of consent

Not applicable.

Data availability statement

Not applicable.

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