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Evaluating the Impact of Ultrasonic Cleaning on the Structural Integrity of Clear Aligners at Varying Temperature

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Abstract

AIM: This study aims to investigate the effects of ultrasonic cleaning at varying temperatures on the structural integrity, fit, and cleanliness of clear aligners made from different materials, including triple-layered polyurethane, single-layered polyurethane, and PET-G.

METHODOLOGY: Three types of aligner materials were selected for the study: triple-layered polyurethane, single-layered polyurethane, and PET-G. Aligner sets were manufactured and subjected to ultrasonic cleaning at temperatures ranging from 10°C to 60°C for 10 minutes. Following the cleaning process, the aligners were visually inspected for debris removal and checked for fit, shape, and structural changes. The aligners were also examined after multiple retrievals to assess durability and the impact of cleaning.

RESULTS: The ultrasonic cleaning process successfully removed debris and biofilm without causing visible damage. However, at higher temperatures (51–60°C), the fit of the PET-G and single-layered polyurethane aligners became loose, whereas the triple-layered polyurethane aligner maintained its fit and structural integrity. No cracks, shape distortions, or changes in mechanical properties were observed in any of the aligners after 60 retrievals.

CONCLUSION: Ultrasonic cleaning proves effective in removing contaminants and biofilm from clear aligners. However, material properties play a crucial role in determining the durability of aligners under different cleaning conditions. Triple-layered polyurethane aligners demonstrated enhanced resistance to temperature-induced degradation, making them a preferable choice for long-term use. These findings highlight the importance of selecting suitable cleaning methods and materials to preserve both the aesthetic and functional qualities of clear aligners.

Keywords: Clear aligners, ultrasonic cleaning, structural integrity, temperature effects, cleaning methods.

Introduction

The demand for esthetic treatments has been increasing significantly, leading to a rise in the popularity of clear aligners as an alternative to traditional fixed orthodontic appliances. Clear aligners offer several advantages, including improved esthetics, enhanced comfort, reduced pain, and fewer clinic visits compared to fixed orthodontics. Additionally, they facilitate better oral hygiene due to their removability, reducing the risk of plaque accumulation, gingival inflammation, and other oral health issues often associated with traditional braces [1,2].

Clear aligners are made of a series of customized transparent plastic trays that are designed to gradually move teeth into the desired position. When worn for a minimum of 20 hours a day and replaced every two weeks, these aligners can achieve dental movements of approximately 0.25–0.33 mm per tooth (or group of teeth) per aligner. This system allows patients to maintain a higher standard of oral hygiene, as the aligners can be removed for cleaning, which also improves periodontal health by reducing plaque levels, gingival bleeding, and pocket depth [3,4].

Despite these advantages, the accumulation of biofilm on the aligner surface remains a major challenge. Biofilm, a complex community of microorganisms adhered to surfaces in a polymeric matrix, can compromise both the esthetics and health benefits of aligners. The ability to clean the aligners effectively is crucial for maintaining their functionality and the patient's oral health. Various cleaning methods are available, including mechanical methods such as brushing with toothpaste or using vibrations, and

chemical methods like the use of antibacterial substances or effervescent tablets [5].

One of the challenges that patients face is ensuring the long-term durability of aligners while cleaning them. The material properties of the aligners, such as their susceptibility to water absorption and temperature-induced degradation, can affect their longevity. Studies have shown that factors like temperature changes, long-term intra-oral use, and cleaning methods can impact the surface morphology and mechanical properties of the aligner material [6,7].

Ultrasonic cleaning has been proposed as an effective method for cleaning aligners due to its ability to remove bacterial contamination through cavitation. However, it is important to assess the impact of ultrasonic cleaning on aligners made from different materials, particularly in terms of potential structural damage that may occur at varying temperatures [8].

This article aims to investigate the effects of ultrasonic cleaning on aligners at different temperatures, examining the potential changes in their structural integrity, fit, and cleanliness.

MATERIAL AND METHODS:

- Aligners of 3 different material types was used in the flow for the Manufacturing Process
- Ultrasonic Cleaning Machine (35KHz)
- Operators for performing and assessing cleaning and deformation

Procedure:

1. Three different types of aligner sheets material were used for this study on the same person model

i. Triple layered polyurethane sheet (TLP)

ii. Single layered polyurethane sheet (SLP)

iii. Polyethylene terephthalate glycol (Pet-G) sheet

2. Selected set of aligners were manufactured as per Standard manufacturing process upto Final Quality Check (QC) stage.

3. After Final QC was done in which cracks, fitting of aligner, distortion, shape, extension margins and strength of each aligners were checked and images were taken (Figure 1).

4. Aligners were cleaned in ultrasonic cleaning machine in temperature ranges of 10-20, 21-30, 31-40, 41-50, 51-60 degree Celsius for 10 minutes (Figure 2).

5. Aligners were checked visually for cleaning of debris post ultrasonic cleaning process (Figure 3).

6. Images were taken post ultrasonic cleaning of aligners (Figure 4) for each temperature range and sheet types.

7. Aligners from each temperature range and sheet type was checked in patients mouth for fitting after cleaning and was checked again for crack, shape change and fitting post 60 retrieval on models.

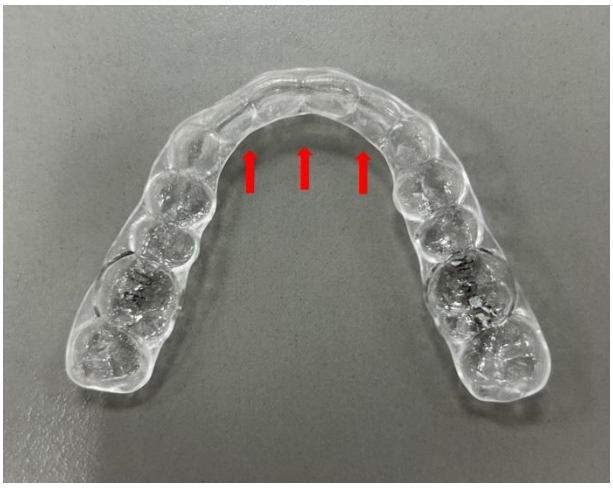

Figure 1 : Pre ultrasonic cleaning image of aligners from 21-30 degree range.

Figure 2: Ultrasonic machine set at 10 minute cycle

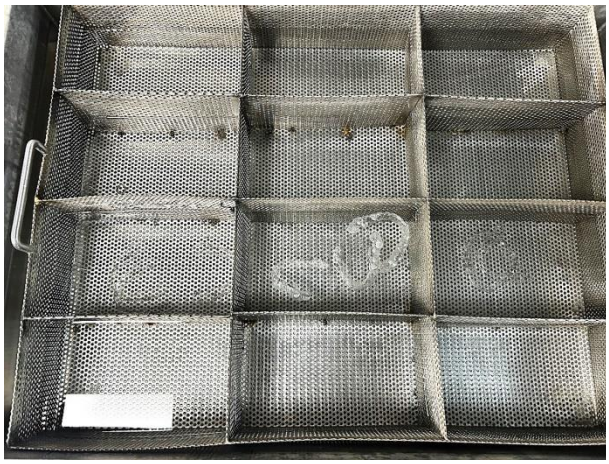

Figure 3: Ultrasonic cleaning of aligners

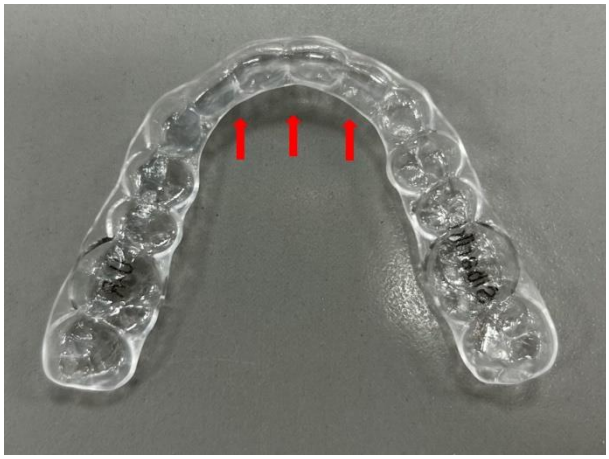

Figure 4: Post ultrasonic cleaning image of aligners from 21-30 degree range

Results:

- It was found that the fit of the PET-G and single-layered polyurethane aligners was loose in the oral cavity at the temperature range of 51-60°C; however, the fit of the triple-layered polyurethane aligner did not change.
- No cracks or shape changes were found in any aligner after 60 retrievals.
- No debris was found visually after ultrasonic cleaning.

Discussion:

The increasing demand for esthetic and comfortable orthodontic solutions has led to the growing popularity of clear aligners. These aligners offer distinct advantages over traditional fixed orthodontic appliances, such as improved oral hygiene, less discomfort, and fewer clinic visits. However, a significant challenge remains in maintaining the aligners, particularly in terms of cleaning and ensuring their durability over time. Proper care is crucial for preserving both the aesthetic appearance of the aligners and the patient's oral health [1,2].

Material Properties of Clear Aligners

Clear aligners are primarily made from thermoplastic materials like polyester, polyurethane, and polypropylene. Among these, Poly(ethylene terephthalate)-glycol (PETG) stands out due to its excellent mechanical properties, formability, and dimensional stability. PETG is a non-crystallizing copolymer of polyethylene terephthalate (PET), which makes it highly suitable for orthodontic applications. On the other hand, Thermoplastic Polyurethane (TPU) is a versatile engineering thermoplastic with elastomeric properties, offering the mechanical characteristics of vulcanized rubber while being processable like thermoplastic polymers. These materials are favoured for their strength, flexibility, and ability to adapt to various orthodontic treatments [6].

However, these materials are susceptible to water absorption, which can lead to degradation. The process of hydrolysis, caused by water interacting with the polymer backbone, can result in irreversible damage to the material. This may cause dimensional changes in the aligners, affecting their fit and the orthodontic forces they exert. As a result, an ideal thermoplastic material for clear aligners should have low water absorption properties to prevent such degradation [6].

Biofilm Formation and Its Impact on Aligners

A major concern in the use of clear aligners is the accumulation of biofilm, which can com-promise both the aligner's aesthetic quality and the patient's oral health. Studies have shown that periodontal pathogens and cariogenic bacteria like Aggregatibacter actinomycetemcomi-tans, Fusobacterium nucleatum, Porphyromonas gingivalis, and Streptococcus mutans can colonize the surface of aligners, leading to plaque buildup and gingival inflammation [5]. The biofilm on aligners is particularly difficult to remove due to the non-exfoliative nature of the microorganisms' attachment to the aligner's surface. As biofilms are highly resistant to chemical and pharmaceutical agents, improper cleaning

methods can allow these harmful microorganisms to thrive [9].

Gracco et al. demonstrated that clear aligners can develop microcracks, abrasions, and de-laminated areas after being worn for just 14 days, which are ideal environments for bacterial adhesion and growth. Additionally, localized calcified biofilm deposits and loss of transparency can occur, further compromising the aligner's esthetics [8].

Cleaning Methods and Their Effectiveness

Several cleaning methods have been suggested to maintain clear aligners and prevent biofilm buildup. Research has highlighted the effectiveness of ultrasonic cleaning, which uses cavitation (the formation and collapse of bubbles) to remove bacteria. Studies, such as those by Moshiri et al., recommend ultrasonic cleaning as part of a comprehensive home hygiene protocol for clear aligner patients. This method has been shown to efficiently remove bacteria and debris from aligners, but the potential impact of ultrasonic cleaning on the structural integrity of aligner materials requires further investigation [10].

A recent study by Luca et al. using scanning electron microscopy observed that ultrasonic cleaning could lead to surface damage, such as pitting and water absorption, likely due to the cavitation process. This finding suggests that while ultrasonic cleaning is effective for bacterial removal, it may also cause physical alterations to the aligner's surface, particularly in thermoplastic polyurethane materials [11].

Findings of the Present Study

This study aimed to evaluate the effects of ultrasonic cleaning at varying temperatures on the structural integrity and fit of aligners made from three different materials: PET-G, SLP, and TLP. Our results revealed that ultrasonic cleaning at higher temperatures (51-60°C) caused significant loosening of the fit for PET-G and SLP aligners. This is likely due to the degradation of material properties at elevated temperatures, making these materials more flexible and less durable under thermal stress.

In contrast, the triple-layered polyurethane aligner maintained its fit and structural integrity across all tested temperature ranges. This supports the hypothesis that multi-layered materials may offer enhanced stability and durability, making them more suitable for long-term use, especially under varying temperature conditions.

Furthermore, no cracks or shape distortion were observed in any of the aligners after multiple retrievals and cleanings. This suggests that the ultrasonic cleaning process, within the tested temperature ranges, does not cause significant physical damage to the aligners. The absence of visible debris after cleaning also indicates that ultrasonic cleaning is effective at removing contaminants, which is crucial for maintaining both the aesthetic appearance and the oral health benefits of clear aligners.

Limitations and Future Research

While this study provides valuable insights, it has several limitations. First, the research only examined three specific types of aligner materials. It would be beneficial to expand this study to include a broader range of materials to gain a comprehensive understanding of ultrasonic cleaning's effects. Additionally, the study was conducted using a bench model, which may not perfectly replicate the conditions in a patient's mouth. Further clinical trials are necessary to confirm the findings and assess the long-term consequences of ultrasonic cleaning on aligners in real-world scenarios.

Conclusion:

This study underscores the importance of selecting appropriate cleaning methods and temperature controls when maintaining clear aligners. Ultrasonic cleaning proves to be an effective method for removing debris and biofilm, but careful attention must be paid to the material properties of the aligners to avoid degradation. Multi-layered materials like triple-layered polyurethane show enhanced durability under thermal stress, making them a preferable choice for long-term use. Clinicians should be aware of the varying responses of different aligner materials to cleaning methods and provide patients with appropriate care instructions to ensure the longevity and effectiveness of their aligners.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflict of interest: No

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