

Evaluation of Colour Stability of Orthodontic Ceramic Brackets and Esthetic Wires Following Immersion in Different Mouthwashes: An In Vitro Study

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ABSTRACT

Introduction: Esthetic orthodontic appliances are increasingly preferred by patients who are concerned about appearance during treatment. Ceramic brackets and coated arch wires provide a less noticeable alternative to conventional metallic appliances; however, their appearance may change following regular exposure to oral hygiene products such as mouthwashes. The colour stability of these materials is therefore important for maintaining esthetics throughout orthodontic treatment. **Aim and Objectives:** The study aimed to evaluate the colour stability of monocrystalline and polycrystalline ceramic brackets and Teflon-, ceramic-, and epoxy-coated esthetic arch wires after exposure to Listerine, fluoride-containing, and probiotic mouthwashes. **Materials and Methodology:** A total of 100 specimens were evaluated, including 40 ceramic brackets (20 monocrystalline and 20 polycrystalline) and 60 esthetic arch-wire segments (20 each of Teflon-, ceramic-, and epoxy-coated wires). Each material was divided into four subgroups and exposed to Listerine, fluoride-containing mouthwash, probiotic mouthwash, or distilled water as the control. Colour changes (ΔE) were recorded at different time intervals, and the data were analysed using repeated-measures ANOVA. **Results:** A gradual increase in colour change was observed in all materials over time, with statistically significant differences ($p = 0.001$). Polycrystalline brackets generally showed slightly more discolouration than monocrystalline brackets. Among the arch wires, epoxy-coated wires showed greater colour change in Listerine and fluoride mouthwashes, while ceramic-coated wires showed slightly higher values in probiotic mouthwash. Only minor changes were observed in the control groups. **Discussion:** Although colour changes increased with exposure time, the values remained well below the clinically perceptible level. The response varied slightly depending on the type of bracket, wire coating, and mouthwash used. Probiotic mouthwash produced comparatively less colour change in ceramic brackets. Overall, the observed changes were small and unlikely to affect the clinical appearance of the tested materials. **Conclusion:** Within the limitations of this in-vitro study, ceramic brackets and esthetic-coated arch wires showed good colour stability in all three mouthwashes. Although small changes in colour occurred over time, these changes were unlikely to be clinically noticeable. The findings suggest that the tested mouthwashes have minimal effect on the colour stability of these esthetic orthodontic materials.

Keywords: Colour stability, ceramic brackets, esthetic arch wires, Listerine, fluoride mouthwash, probiotic mouthwash, orthodontics.

INTRODUCTION

Aesthetics has become an important consideration in modern orthodontic treatment. Along with functional correction, patients increasingly prefer appliances that are less noticeable, particularly adolescents and adults. This growing demand has led to the widespread use of ceramic brackets and esthetic arch wires as alternatives to conventional metallic appliances [1,2]. Ceramic brackets are mainly available as monocrystalline and polycrystalline alumina brackets. Monocrystalline brackets are generally more translucent, whereas polycrystalline brackets have a relatively opaque appearance due to light scattering at grain boundaries [3]. Similarly, esthetic arch wires are commonly made of nickel-titanium or stainless steel and coated with Teflon, epoxy resin, or ceramic materials to improve their appearance [4,5].

Despite their aesthetic advantages, colour stability remains a concern. During orthodontic treatment, brackets and wires are continuously exposed to saliva, food, beverages, and oral hygiene products, which may alter their original colour. The extent of discolouration depends on factors such as material composition, surface roughness, coating integrity, type of staining agent, and duration of exposure [3,5,6]. Surface defects and microcracks in coated wires may further increase pigment retention and accelerate colour changes [5]. Colour changes in orthodontic materials can be objectively evaluated using the CIE $L^*a^*b^*$ colour system, where L^* represents lightness, a^* the red–green axis, and b^* the yellow–blue axis. The overall colour difference is expressed as ΔE , with higher values indicating greater colour alteration. Spectrophotometric assessment using this system provides an objective and reproducible method for evaluating colour stability [4].

Mouthwashes are frequently recommended during fixed orthodontic treatment to control plaque, gingival inflammation, halitosis, and dental caries. However, their regular use may affect the colour stability of esthetic orthodontic materials [3,9,10]. Commercial mouthwashes contain different active ingredients, including chlorhexidine, fluoride, alcohol, and essential oils, which may interact differently with ceramic brackets and coated wires. Chlorhexidine is particularly associated with extrinsic staining, while alcohol-containing and acidic formulations may affect polymer-based coatings and increase their susceptibility to discolouration [7,9,10]. Previous studies have reported colour changes in ceramic brackets and esthetic wires following exposure to staining agents such as coffee, tea, cola, wine, and mouthwashes [1,3,4,6,7]. However, comparatively fewer studies have evaluated the effect of different mouthwash formulations on both ceramic

brackets and esthetic arch wires. Direct comparisons between different types of ceramic brackets and esthetic wire coatings also remain limited [1,4,5].

Considering the increasing use of esthetic orthodontic appliances and mouthwashes during treatment, evaluating their interaction is clinically relevant. Therefore, the present in vitro study aims to evaluate and compare the colour stability of orthodontic ceramic brackets and esthetic arch wires following immersion in different mouthwashes. The findings may help clinicians select materials with better colour stability and recommend appropriate mouthwashes to patients undergoing esthetic orthodontic treatment.

AIMS AND OBJECTIVES

AIM

Evaluation of Colour Stability of Orthodontic Ceramic Brackets and Esthetic Wires Following Immersion in Different Mouthwashes

OBJECTIVES

1. To evaluate the colour stability of monocrystalline and polycrystalline ceramic brackets following immersion in Listerine mouthwash.
2. To evaluate the colour stability of monocrystalline and polycrystalline ceramic brackets following immersion in a fluoride-containing mouthwash.
3. To evaluate the colour stability of monocrystalline and polycrystalline ceramic brackets following immersion in a probiotic mouthwash.
4. To evaluate the colour stability of Teflon-coated esthetic arch wires following immersion in Listerine, fluoride-containing, and probiotic mouthwashes.
5. To evaluate the colour stability of epoxy-coated esthetic arch wires following immersion in Listerine, fluoride-containing, and probiotic mouthwashes.
6. To evaluate the colour stability of ceramic-coated esthetic arch wires following immersion in Listerine, fluoride-containing, and probiotic mouthwashes.

MATERIALS AND METHODOLOGY

The present in vitro study was conducted in the Postgraduate Department of Orthodontics and Dentofacial Orthopedics, MMCDJR, Mullana.

Study Design

The study will be designed as a laboratory-based in vitro experimental study to evaluate the colour stability of

ceramic orthodontic brackets and esthetic arch wires following exposure to different mouthwashes under standardized conditions.

Two types of ceramic brackets-monocrystalline and polycrystalline-and three types of esthetic arch wires-Teflon-coated, epoxy-coated, and ceramic-coated-will be evaluated. Three commercially available mouthwashes will be used as test solutions: Listerine, fluoride-containing mouthwash, and probiotic mouthwash. Distilled water will serve as the control.

Sample Preparation

A total of 40 ceramic brackets will be included:

- 20 monocrystalline ceramic brackets (Osstem)
- 20 polycrystalline ceramic brackets (Ortho Organizers)

Each bracket type will be divided into four subgroups of five specimens according to the immersion solution. For the esthetic arch wires, 20 segments from each type of coated wire will be prepared, giving a total of 60 wire specimens:

- 20 Teflon-coated wire segments
- 20 ceramic-coated wire segments
- 20 epoxy-coated wire segments

Each wire group will similarly be divided into four subgroups of five specimens. Thus, the study will include a total of 100 specimens: 40 ceramic brackets and 60 esthetic wire segments.

Inclusion Criteria

1. Monocrystalline ceramic brackets for anterior teeth.
2. Polycrystalline ceramic brackets for anterior teeth.
3. Teflon-coated esthetic arch wires.
4. Epoxy-coated esthetic arch wires.
5. Ceramic-coated esthetic arch wires.
6. Listerine mouthwash.
7. Fluoride-containing mouthwash.
8. Probiotic mouthwash.

Exclusion Criteria

1. Posterior ceramic brackets.
2. Brackets with visible manufacturing defects or surface damage.
3. Metallic brackets.
4. Rhodium-coated wires.
5. Uncoated metallic wires.
6. Uncoated nickel-titanium wires.
7. Wire segments with visible defects or damaged coatings.

Study Groups

I. Ceramic Brackets

The 40 ceramic brackets will be divided into two main groups according to the type of ceramic.

Group A – Monocrystalline Ceramic Brackets (n = 20)

- A1 (n = 5): Listerine mouthwash
- A2 (n = 5): Fluoride-containing mouthwash
- A3 (n = 5): Probiotic mouthwash
- A4 (n = 5): Distilled water (control)

Group B – Polycrystalline Ceramic Brackets (n = 20)

- B1 (n = 5): Listerine mouthwash
- B2 (n = 5): Fluoride-containing mouthwash
- B3 (n = 5): Probiotic mouthwash
- B4 (n = 5): Distilled water (control)

Each specimen will be exposed to its respective solution for 30 seconds daily for 8 weeks.

II. Esthetic Arch Wires

The 60 esthetic arch-wire segments will be divided into three main groups according to the type of coating.

Group C – Teflon-Coated Arch Wires (n = 20)

- C1 (n = 5): Listerine mouthwash
- C2 (n = 5): Fluoride-containing mouthwash
- C3 (n = 5): Probiotic mouthwash
- C4 (n = 5): Distilled water (control)

Group D – Ceramic-Coated Arch Wires (n = 20)

- D1 (n = 5): Listerine mouthwash
- D2 (n = 5): Fluoride-containing mouthwash
- D3 (n = 5): Probiotic mouthwash
- D4 (n = 5): Distilled water (control)

Group E – Epoxy-Coated Arch Wires (n = 20)

- E1 (n = 5): Listerine mouthwash
- E2 (n = 5): Fluoride-containing mouthwash
- E3 (n = 5): Probiotic mouthwash
- E4 (n = 5): Distilled water (control)

All wire specimens will be exposed to their respective solutions for 30 seconds daily for 8 weeks.

Immersion Protocol

Each specimen will be assigned to its designated test or control solution. The brackets and wire segments will be immersed individually in the respective mouthwash for 30 seconds once daily. Specimens in the control groups will undergo the same procedure using distilled water.

The immersion protocol will be continued for 8 weeks under standardized laboratory conditions to ensure uniform exposure across all group.

RESULTS

Mean Colour Change of Ceramic Brackets Following Immersion in Listerine Mouthwash

Table 1. Mean Colour Change of Ceramic Brackets Following Immersion in Listerine Mouthwash

			Repeated Measures ANOVA	
Time	Monocrystalline Bracket	Polycrystalline Bracket	F value	P value
T0	0.019	0.059	2368.820	0.001
T1	0.143	0.154		
T2	0.153	0.164		
T3	0.285	0.307		

Table 1 present the mean colour change (ΔE) observed in monocrystalline and polycrystalline ceramic brackets exposed to Listerine mouthwash at different time intervals. Both bracket types showed a gradual increase in colour change from T0 to T3. However, polycrystalline brackets exhibited slightly greater discolouration than monocrystalline brackets. Repeated-measures ANOVA showed a statistically significant change over time ($p = 0.001$), suggesting that longer exposure to Listerine was associated with greater colour alteration in both types of ceramic brackets.

Mean Colour Change (ΔE) of Ceramic Brackets Following Immersion in Fluoride-Containing Mouthwash

Table 2. Mean Colour Change (ΔE) of Ceramic Brackets Following Immersion in Fluoride-Containing Mouthwash

			Repeated Measures ANOVA	
Time	Monocrystalline Bracket	Polycrystalline Bracket	F value	P value
T0	0.019	0.059	4627.665	0.001
T1	0.166	0.164		
T2	0.176	0.174		
T3	0.257	0.303		

Table 2 show a gradual increase in colour change (ΔE) in both ceramic bracket types over time. Polycrystalline brackets showed slightly greater discolouration than monocrystalline brackets. This change was statistically significant ($p = 0.001$), indicating that longer exposure to fluoride mouthwash increased discolouration.

Mean Colour Change (ΔE) of Ceramic Brackets in Probiotic Mouthwash

Table 3. Mean Colour Change (ΔE) of Ceramic Brackets in Probiotic Mouthwash

			Repeated Measures ANOVA	
Time	Monocrystalline Bracket	Polycrystalline Bracket	F value	P value
T0	0.019	0.059	24809.368	0.001
T1	0.1256	0.1442		
T2	0.1354	0.1542		
T3	0.1936	0.2730		

Table 3 show that both types of ceramic brackets gradually changed colour with increasing exposure time. The degree of discolouration was relatively lower with probiotic mouthwash compared with the other mouthwashes. However, the change over time was statistically significant ($p = 0.001$).

Mean Colour Change of Ceramic Brackets in Control Mouthwash

Table 4: Mean Colour Change of Ceramic Brackets in Control Mouthwash

			Repeated Measures ANOVA	
Time	Monocrystalline Bracket	Polycrystalline Bracket	F value	P value
T0	0.019	0.059	3084.623	0.001
T1	0.025	0.029		
T2	0.035	0.030		
T3	0.180	0.180		

Table 4 show minimal colour change in both ceramic bracket types when kept in the control solution. The values remained fairly stable throughout the study, with only a slight increase at T3. Both monocrystalline and polycrystalline brackets showed a similar pattern, indicating that the control solution had little effect on their colour stability over time.

Mean Colour Change (ΔE) of Esthetic Arch Wires in Listerine Mouthwash

Table 5: Mean Colour Change (ΔE) of Esthetic Arch Wires in Listerine Mouthwash

				Repeated Measures ANOVA	
Time	Teflon-Coated	Ceramic-Coated	Epoxy-Coated	F value	P value
T0	0.076	0.040	0.017	3126.123	0.001
T1	0.123	0.112	0.113		
T2	0.133	0.140	0.123		
T3	0.216	0.246	0.283		

Table 5 show that all three types of esthetic arch wires gradually changed colour with increasing exposure to Listerine mouthwash. Among them, epoxy-coated wires showed the greatest colour change at the later time intervals. The change over time was statistically significant ($p = 0.001$), indicating that prolonged exposure to Listerine affected the colour stability of the coated wires.

Mean Colour Change (ΔE) of Esthetic Arch Wires in Fluoride-Containing Mouthwash

Table 6: Mean Colour Change (ΔE) of Esthetic Arch Wires in Fluoride-Containing Mouthwash

				Repeated Measures ANOVA	
Time	Teflon-Coated	Ceramic-Coated	Epoxy-Coated	F value	P value
T0	0.076	0.040	0.017	7438.256	0.001
T1	0.1322	0.1265	0.1286		
T2	0.1438	0.1365	0.1306		
T3	0.2800	0.2800	0.3000		

Table 6 show a gradual increase in colour change in all three types of esthetic arch wires with increasing exposure to fluoride mouthwash. Epoxy-coated wires showed greater discolouration than the other coated wires, particularly at the later time intervals. The change over time was statistically significant ($p = 0.001$).

Mean Colour Change (ΔE) of Esthetic Arch Wires in Probiotic Mouthwash

Table 7. Mean Colour Change (ΔE) of Esthetic Arch Wires in Probiotic Mouthwash

				Repeated Measures ANOVA	
Time	Teflon-Coated	Ceramic-Coated	Epoxy-Coated	F value	P value
T0	0.076	0.040	0.017	386.346	0.001
T1	0.116	0.106	0.105		
T2	0.126	0.116	0.115		
T3	0.240	0.315	0.242		

Table 7 and Graph 7 show a gradual increase in colour change in all three types of esthetic arch wires over time. Ceramic-coated wires showed slightly greater discolouration at the later time intervals. The change from T0 to T3 was statistically significant ($p = 0.001$).

Mean Colour Change (ΔE) of Esthetic Arch Wires in Control Solution

Table 8. Mean Colour Change (ΔE) of Esthetic Arch Wires in Control Solution

				Repeated Measures ANOVA	
Time	Teflon-Coated	Ceramic-Coated	Epoxy-Coated	F value	P value
T0	0.076	0.040	0.017	3081.632	0.001
T1	0.100	0.080	0.028		
T2	0.020	0.090	0.038		
T3	0.177	0.177	0.177		

Table 8 show that the colour of all three esthetic arch wires remained fairly stable in the control solution, with only a slight change over time. By T3, the three wire types showed similar colour change values. Although the overall change was small, it was statistically significant ($p = 0.001$).

DISCUSSION

The present study evaluated the colour stability of ceramic brackets and esthetic-coated arch wires following exposure to Listerine, fluoride-containing, and probiotic mouthwashes. Overall, colour change (ΔE) increased gradually with time in all groups. Although these changes were statistically significant ($p = 0.001$), their magnitude remained well below the clinically perceptible threshold, suggesting that the observed changes were unlikely to be noticeable clinically. Both monocrystalline and polycrystalline ceramic brackets showed good colour stability throughout the study. Polycrystalline brackets generally showed slightly greater discolouration than monocrystalline brackets, which may be related to their multiple crystal grain boundaries and greater tendency for surface adsorption. Similar differences in the colour stability of ceramic brackets have been reported by Oliveira et al. [12] and Lopes Filho et al. [13], although the colour changes reported in these studies were considerably greater than those observed in the present study.

Among the tested solutions, probiotic mouthwash produced comparatively less colour change in ceramic brackets. Listerine and fluoride mouthwash produced slightly greater changes, but the values remained clinically negligible. Previous studies by Barros et al. [14], Šimunović et al. [3], and Al-Joubori et al. [11] reported higher ΔE values with different mouthwashes and staining solutions. The lower values in the present study indicate good resistance of ceramic brackets to discolouration under the tested conditions. Esthetic arch wires also showed a gradual increase in colour change with time. Epoxy-coated wires showed greater discolouration in Listerine and fluoride mouthwashes, whereas ceramic-coated wires showed slightly higher values in probiotic mouthwash. These differences may be related to the surface characteristics of the coatings. Epoxy coatings may have greater water sorption and surface porosity, while the hydrophobic nature of Teflon may provide better resistance to surface changes.

The findings are in agreement with Anand et al. [4], who reported greater colour change in epoxy-coated than Teflon-coated arch wires following mouthwash

exposure. However, the ΔE values in their study were considerably higher than those observed in the present investigation. Similarly, Al-Joubori et al. [11] reported greater colour changes in coated arch wires exposed to fluoridated and non-fluoridated mouthwashes. Both ceramic brackets and esthetic arch wires showed only minor colour changes in the control solution. The values remained fairly stable, and the materials showed similar colour changes at the final interval. These small changes may be related to surface hydration, water sorption, or minor changes in light reflection rather than actual staining [15,16,17].

Overall, the findings show that prolonged exposure to mouthwashes can produce small, measurable changes in the colour of esthetic orthodontic materials. However, despite being statistically significant, these changes remained clinically negligible. Both ceramic brackets and coated arch wires therefore demonstrated good colour stability in Listerine, fluoride-containing, and probiotic mouthwashes under the conditions of the present study.

Strengths of the Study

The major strengths of the present study include the evaluation of both monocrystalline and polycrystalline ceramic brackets, along with three commonly used esthetic orthodontic wire coatings, namely Teflon-coated, ceramic-coated, and epoxy-coated wires. The study also compared the effects of different types of mouthwashes, including Listerine, fluoride-containing mouthwash, and probiotic mouthwash, with distilled water serving as a control. A standardized immersion protocol of 30 seconds daily for 8 weeks was used to simulate repeated exposure to mouthwashes. Colour changes were evaluated at multiple time points, allowing assessment of the progression of colour alteration over the study period. The use of objective colour assessment based on the CIE Lab* system and ΔE values provides a quantitative approach for evaluating colour stability.

Limitations of the Study

The present study has several limitations. First, it was an in vitro study and therefore the experimental conditions may not completely reproduce the complex oral environment. Factors such as saliva, salivary flow, temperature fluctuations, dietary staining agents, plaque accumulation, and mechanical abrasion were not fully replicated. Second, the sample size within each subgroup was relatively small, which may limit the generalizability of the findings. Third, the specimens were exposed to mouthwashes under a standardized immersion protocol, which may differ from the actual pattern and duration of mouthwash use in clinical practice. In addition, only selected ceramic bracket

types, esthetic wire coatings, and mouthwash formulations were evaluated. Therefore, the findings should be interpreted within the scope of the materials and experimental conditions investigated. Further clinical studies with larger sample sizes and longer follow-up are required to confirm the present findings.

Future Directions

Future studies should include larger sample sizes and clinically relevant experimental conditions to improve the generalizability of the findings. In vivo studies are warranted to evaluate the colour stability of ceramic brackets and esthetic wires under actual oral conditions, including exposure to saliva, dietary chromogens, temperature variations, plaque, and mechanical forces. Further research should also compare a wider range of mouthwash formulations and esthetic orthodontic materials, with longer observation periods to determine their long-term colour stability. Clinical studies correlating instrumental ΔE measurements with patients' and clinicians' perception of clinically noticeable colour changes may provide additional evidence regarding the practical significance of colour alteration.

CONCLUSION

The present in-vitro study showed that both ceramic brackets and esthetic-coated arch wires maintained good colour stability following exposure to Listerine, fluoride-containing, and probiotic mouthwashes. Although colour change (ΔE) increased significantly with time ($p = 0.001$), the overall changes remained well below the clinically perceptible threshold. Thus, the changes detected during the study were measurable but unlikely to be noticeable clinically.

Polycrystalline ceramic brackets showed slightly greater discolouration than monocrystalline brackets. Among the esthetic arch wires, the degree of colour change varied with the type of coating and mouthwash used, although these differences remained small. Probiotic mouthwash produced comparatively less colour change in ceramic brackets, while the control groups showed only minimal changes. Overall, the findings suggest that the tested ceramic brackets and esthetic arch wires retain satisfactory colour stability during exposure to the evaluated mouthwashes.

Declarations

Ethics Approval

As this was an in vitro experimental study involving commercially available orthodontic materials and no human or animal participants, formal ethical approval was not applicable, in accordance with the policies of the relevant institution.

Consent to Participate

Not applicable, as no human participants were involved in the study.

Consent for Publication

Not applicable.

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Conflict of Interest:

The authors declare that they have no conflict of interest.

Data Availability Statement

The data generated and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Author Contributions

All authors contributed to the conception and design of the study, data collection and/or analysis, interpretation of the results, preparation and critical revision of the manuscript, and approved the final version of the manuscript.

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