

Shade Stability of Monolithic Zirconia Crown in Tobacco Users: A Comparative in Vivo Study

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Abstract

Aim: The Aim of this study is to evaluate and compare the color stability of monolithic zirconia restorations in different groups of patients: non- tobacco users, smokers, smokeless tobacco users and dual users (smoking & smokeless tobacco) at baseline, after 6 months and after 12 months.

Material and Methodology: This in vivo study was conducted in the Department of Prosthodontics at

Hitkarini Dental College on 80 patients requiring monolithic zirconia crown and bridge restorations. Subjects were equally divided into four groups: non-tobacco users, smokers, smokeless tobacco users, and dual users (smokers + smokeless tobacco users). Standardized tooth preparation, provisionalization, CAD/CAM fabrication, and cementation procedures were performed for all restorations. Shade evaluation was carried out using the VITA Easyshade® V

spectrophotometer under standardized conditions. Baseline shade values were recorded immediately after cementation and reassessed at 6 months and 12 months using the CIELAB color system. Statistical analysis was performed using SPSS version 23.0, and a P value <0.05 was considered statistically significant.

Results: At 6 months, no statistically significant difference in shade stability was observed among the study groups ($P > 0.05$). However, at 12 months, tobacco users demonstrated significantly greater discoloration of monolithic zirconia restorations compared to non-tobacco users ($P < 0.05$). Complete shade stability was maintained in non-tobacco users, whereas shade changes were observed in 70% of smokers, 75% of smokeless tobacco users, and 90% of dual users. Dual users exhibited the highest degree of discoloration, indicating that prolonged tobacco exposure adversely affects the long-term color stability of monolithic zirconia restorations.

Conclusion: Monolithic zirconia crowns demonstrated excellent short-term shade stability; however, prolonged tobacco exposure significantly compromised long-term color stability. Non-tobacco users maintained superior esthetic outcomes, whereas smokers, smokeless tobacco users, and dual users showed progressive discoloration over 12 months, with dual users exhibiting the greatest shade change. The findings suggest that cumulative duration of tobacco exposure, rather than the specific form of tobacco, is the primary factor affecting shade instability in monolithic zirconia restorations.

Clinical significance: Although monolithic zirconia exhibits excellent initial shade stability, prolonged tobacco exposure adversely affects its long-term esthetic performance. Tobacco history should therefore be considered during treatment planning, and patients should be informed about the potential for discoloration

and the importance of maintenance and tobacco cessation for preserving esthetic outcomes.

Keywords: Shade Stability, Monolithic Zirconia, Spectrophotometer, Tobacco Use, VITA Easy Shade, Fixed Prosthodontics

Introduction

Aesthetic rehabilitation is an integral component of contemporary prosthodontics, with increasing emphasis on patient-centered care, esthetics, and quality of life. In fixed prosthodontics, the success of a restoration depends not only on its functional durability but also on its long-term esthetic performance.¹ Advances in all-ceramic restorative materials have significantly improved the ability to achieve restorations that closely mimic the appearance of natural dentition. Among these materials, zirconia has gained widespread popularity because of its excellent mechanical properties, biocompatibility, and favorable esthetic characteristics.^{2,3}

Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) exhibits high flexural strength and fracture resistance, making it suitable for stress-bearing posterior restorations.² The introduction of monolithic zirconia restorations has further improved the clinical performance of zirconia by eliminating veneering porcelain, thereby reducing the incidence of porcelain chipping commonly associated with layered zirconia systems.^{4,5} Improvements in translucency, grain size distribution, yttria concentration, and coloring techniques have enhanced the esthetic potential of monolithic zirconia restorations.⁶

Shade stability is an essential requirement for the long-term esthetic success of restorative materials. It refers to the ability of a material to maintain its original color over time despite exposure to various intraoral conditions.⁷ Factors such as saliva, temperature changes, dietary habits, oral hygiene practices, and surface characteristics

of restorations may influence color stability.^{8,9} Tobacco consumption is considered one of the most significant extrinsic factors contributing to discoloration of both natural teeth and dental restorations.^{9,10}

India has a high prevalence of tobacco consumption in both smoked and smokeless forms, including cigarettes, bidis, gutkha, khaini, and pan masala.¹¹ Tobacco products contain nicotine, tar, and other chromogenic substances that may adhere to restorative surfaces and alter their optical properties over time.^{12,13} Although ceramic materials generally demonstrate superior color stability compared with resin-based restorative materials, zirconia restorations may still undergo discoloration depending on surface finish, glazing, polishing procedures, and oral environmental factors.^{14,15}

Several in vitro investigations have evaluated the color stability of zirconia restorations in different staining media such as coffee, tea, wine, and nicotine solutions.^{16–18} However, laboratory conditions cannot fully reproduce the complex oral environment, including salivary interactions, oral hygiene variations, and long-term tobacco exposure. Therefore, limited clinical evidence is available regarding the shade stability of monolithic zirconia restorations in tobacco users. Objective digital shade analysis systems such as the VITA Easyshade® V spectrophotometer provide reproducible and standardized color assessment using the CIELAB color system.^{20,21}

Hence, the present in vivo study was conducted to evaluate and compare the shade stability of monolithic zirconia crowns in non-tobacco users, smokers, smokeless tobacco users, and dual users over a 12-month follow-up period.

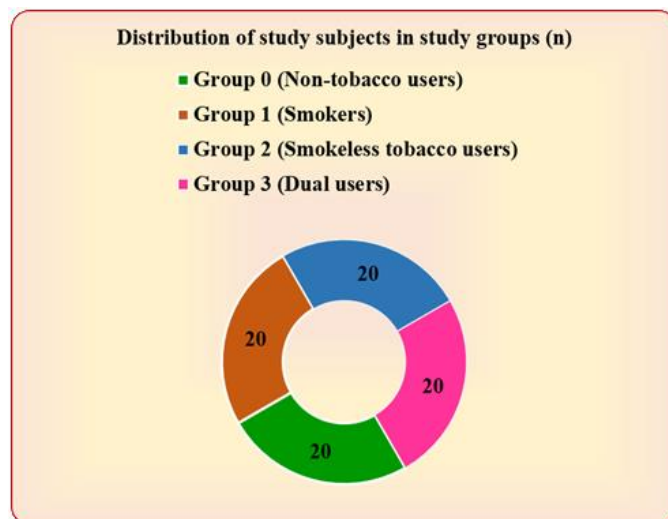
Methodology

This comparative in vivo clinical study was conducted in the Department of Prosthodontics, Hitkarini Dental

College and Hospital, Jabalpur, Madhya Pradesh, India, from April 2024 to July 2025 after obtaining approval from the Institutional Ethical Committee (No. HDC&H/2024/1637/C). Written informed consent was obtained from all participants prior to inclusion in the study.

A total of 80 partially edentulous patients requiring crown and bridge prosthesis were selected and equally divided into four groups (n = 20 each): (Graph 1)

- Group 0 – Non-tobacco users
- Group 1 – Smokers
- Group 2 – Smokeless tobacco users
- Group 3 – Dual users (smokers and smokeless tobacco users)



Graph 1: Distribution of study subjects in study groups
The sample size was determined using G*Power software (version 3.1.9.7) based on pilot study findings, with a confidence interval of 95% and study power of 80%.

Inclusion Criteria

- Patients aged 20–60 years
- Partially edentulous patients requiring fixed prosthodontic treatment
- Non-tobacco users
- Smokers
- Smokeless tobacco users

- Dual users (smoking and smokeless tobacco use)

Exclusion Criteria

- Patients with systemic conditions such as gastroesophageal reflux disease (GERD)
- Patients with active oral infections such as candidiasis
- Patients unwilling to comply with study instructions and follow-up visits

Diagnostic impressions were made using irreversible hydrocolloid impression material, and diagnostic casts were poured in dental stone for treatment planning. Tooth preparation for monolithic zirconia crowns was performed according to standard biomechanical principles with 1.0–1.5 mm occlusal reduction, 0.8–1.0 mm axial reduction, and a deep chamfer finish line. All internal line angles were rounded to reduce stress concentration. Gingival retraction was performed before final impression making to obtain accurate marginal details.

Shade evaluation was carried out under standardized lighting conditions using the VITA Classical Shade Guide and VITA Easyshade® V spectrophotometer. All measurements were performed by the same operator to minimize inter-observer variability.

Provisional restorations were fabricated using bis-acrylic resin material and cemented with non-eugenol temporary cement. Definitive monolithic zirconia restorations were fabricated using CAD/CAM technology from yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) blocks. The restorations were sintered, characterized, glazed, polished, and evaluated for marginal adaptation and occlusion prior to cementation.

The internal surfaces of zirconia restorations were air-abraded with 50 µm aluminum oxide particles and treated with MDP-containing zirconia primer before final cementation. Depending on clinical requirements, self-

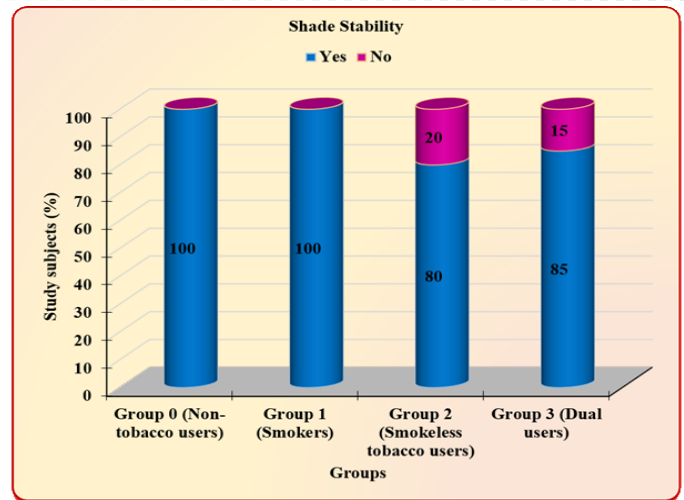
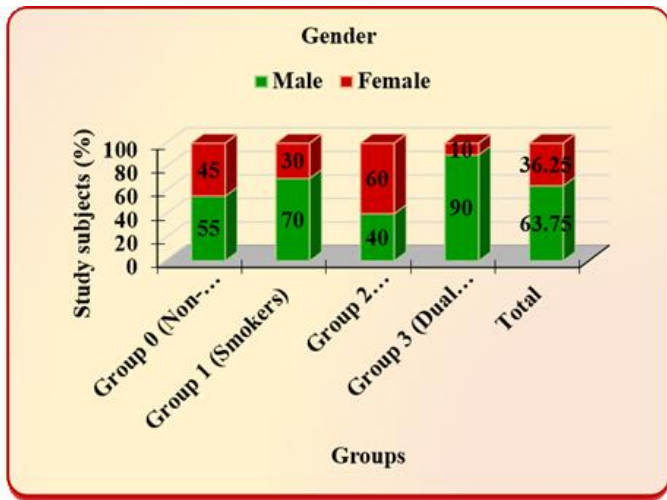
adhesive resin cement or resin-modified glass ionomer cement was used for luting.

Shade measurements were recorded immediately after cementation (baseline), at 6 months, and at 12 months using the VITA Easyshade® V spectrophotometer. The device was calibrated before every use, and recordings were obtained from the middle third of the buccal surface of the restoration under standardized environmental conditions. Three consecutive readings were recorded, and the mean value was considered for analysis.

Statistical analysis was performed using SPSS software version 23.0 (IBM Corporation, Armonk, NY, USA). Descriptive statistics included mean, standard deviation, frequencies, and percentages. One-way ANOVA was used for age comparison, while gender distribution was analyzed using the Chi-square test. Intra-group comparisons of shade stability across time intervals were performed using Cochran's Q test followed by McNemar test with Bonferroni correction. Inter-group comparisons were performed using Chi-square test with Yates' correction wherever applicable. A P value <0.05 was considered statistically significant.

Results

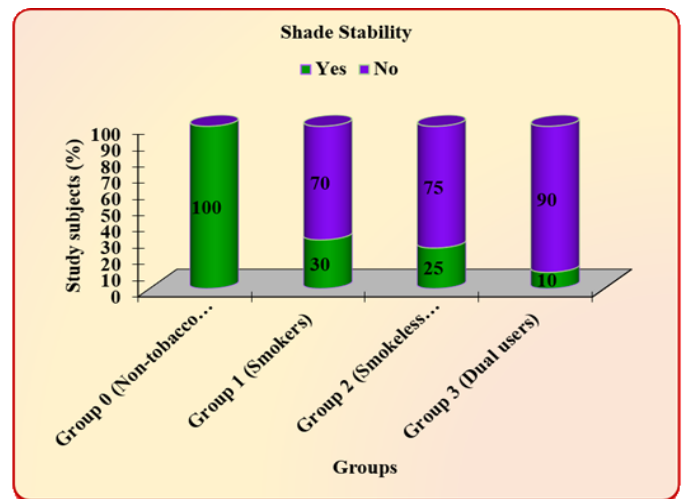
A total of 80 participants were included in the study and equally distributed into four groups consisting of non-tobacco users, smokers, smokeless tobacco users, and dual users. The mean age ranged from 37.00 ± 14.51 years in non-tobacco users to 45.05 ± 11.23 years in dual users, with no statistically significant difference among the groups ($F = 2.013$, $P = 0.119$). Gender distribution differed significantly among the groups ($\chi^2 = 11.846$, $P = 0.008$), with male predominance observed particularly among smokers and dual users. (Graph 2)



Graph 2: Comparison of gender distribution between study groups

Non-tobacco users demonstrated complete shade stability throughout the 12-month follow-up period, with no detectable changes in VITA shade scores. In smokers, no significant shade alteration was observed at 6 months; however, 70% of subjects exhibited darker VITA shades at 12 months, indicating progressive discoloration over time. Smokeless tobacco users demonstrated shade changes in 20% of subjects at 6 months, which increased to 75% at 12 months. Dual users exhibited the highest degree of discoloration, with shade changes observed in 15% of subjects at 6 months and 90% at 12 months. (Graph 3,4) (Table 1,2,3,4)

Graph 3: Inter-group comparison of shade stability of monolithic zirconia crowns from baseline to 6-month follow-up.



Graph 4: Inter-group comparison of shade stability of monolithic zirconia crowns from baseline to 12-month follow-up.

Table 1: Tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 0 (non-tobacco users) at different time points.

Patient no.	Baseline (T ₀)	After 6 months (T ₁)	After 12 months (T ₂)
1	A3.5	A3.5	A3.5
2	A3	A3	A3
3	C4	C4	C4
4	A4	A4	A4
5	C3	C3	C3
6	A3.5	A3.5	A3.5
7	B2	B2	B2

8	A4	A4	A4
9	A4	A4	A4
10	C2	C2	C2
11	C4	C4	C4
12	A3.5	A3.5	A3.5
13	A4	A4	A4
14	A3.5	A3.5	A3.5
15	A3	A3	A3
16	A3	A3	A3
17	A3.5	A3.5	A3.5
18	A3	A3	A3
19	B1	B1	B1
20	C3	C3	C3
Cochran's Q test	Test not applicable		

Table 1 shows tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 0 (non-tobacco users) at different time points (baseline, 6 months, and 12 months). For all 20 patients, the recorded VITA shade at baseline was identical to the shades

recorded at 6-months and 12-months follow up, indicating complete shade stability over the 12-months period in this group. As there was no change in shade for any subject between time points, Cochran's Q test was not applicable for statistical comparison.

Table 2: Tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 1 (Smokers) at different time points.

Patient no.	Baseline (T ₀)	After 6 months (T ₁)	After 12 months (T ₂)
1	A4	A4	A4
2	C2	C2	C3
3	A3.5	A3.5	A3.5
4	A3.5	A3.5	C3
5	A3	A3	B3
6	A3.5	A3.5	A3.5
7	A3.5	A3.5	C4
8	B1	B1	B2
9	C4	C4	C4
10	A2	A2	A3
11	A3	A3	A3.5
12	A3.5	A3.5	A3.5
13	A3.5	A3.5	A4
14	C3	C3	C4
15	A3.5	A3.5	A3.5
16	A3	A3	A3.5

17	C2	C2	C3
18	B2	B2	B3
19	A3.5	A3.5	A4
20	C2	C2	C3
Cochran's Q test	Cochran's Q = 28.000, df = 2, P = 0.000 (<0.05), Significant		
McNemar test (Pairwise comparison with Bonferroni correction)	Baseline (T ₀) and After 6 months (T ₁): Test not applicable Baseline (T ₀) and After 12 months (T ₁): P = 0.000 (<0.017), Significant After 6 months (T ₁) and After 12 months (T ₁): P = 0.000 (<0.017), Significant		

Table 2 shows tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 1 (Smokers) at different time points (baseline, 6 months, and 12 months). No shade change was observed at 6 months compared to baseline, whereas by 12 months a total of 14 patients (70%) showed a shift to darker VITA shades, indicating shade instability over time in smokers. Cochran's Q test demonstrated a statistically significant difference in shade status across the three time points (Q

= 28.000, df = 2, P < 0.05). McNemar tests with Bonferroni correction for pairwise comparison confirmed that there was no analyzable change between baseline and 6 months, but significant shade changes were detected from baseline to 12 months (P < 0.017) and from 6 months to 12 months (P < 0.017), suggesting progressive shade darkening over the 12-months period in smokers.

Table 3: Tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 2 (Smokeless tobacco users) at different time points.

Patient no.	Baseline (T ₀)	After 6 months (T ₁)	After 12 months (T ₂)
1	A4	A4	A4
2	C3	C3	C4
3	C3	C3	C4
4	B4	B4	C4
5	A3.5	A3.5	B4
6	C2	C2	C3
7	A4	A4	A4
8	A3	A3	A3.5
9	A3	A3	A3
10	A4	A4	A4
11	A4	A4	A4
12	A3.5	A3.5	A4
13	A3.5	A4	A4
14	A4	B4	B4

15	A2	A3.5	A3.5
16	C2	C2	C3
17	B2	B2	B3
18	A3	A3	A3.5
19	A2	A3	A3
20	A2	A2	A3
Cochran's Q test	Cochran's Q = 24.133, df = 2, P = 0.000 (<0.05), Significant		
McNemar test (Pairwise comparison with Bonferroni correction)	Baseline (T ₀) and After 6 months (T ₁): P = 0.125 (>0.017), not significant Baseline (T ₀) and After 12 months (T ₁): P = 0.000 (<0.017), Significant After 6 months (T ₁) and After 12 months (T ₁): P = 0.001 (<0.017), Significant		

Table 3 shows tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 2 (Smokeless tobacco users) at different time points (baseline, 6 months, and 12 months). At 6 months, shade change from baseline was observed in 4 patients (20%), and by 12 months a total of 15 patients (75%) showed a shift to darker VITA shades, indicating progressive shade instability in this group. Cochran's Q test demonstrated a statistically significant difference in shade status across

the three time points (Q = 24.133, df = 2, P < 0.05). McNemar tests with Bonferroni correction for pairwise comparison showed that shade change between baseline and 6 months was not statistically significant (P = 0.125; P > 0.017), whereas changes from baseline to 12 months (P = 0.000; P < 0.017) and from 6 to 12 months (P = 0.001; P < 0.017) were statistically significant, confirming additional shade darkening between 6 and 12 months in Smokeless tobacco users.

Table 4: Tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 3 (dual users) at different time points.

Patient no.	Baseline (T ₀)	After 6 months (T ₁)	After 12 months (T ₂)
1	A4	C4	C4
2	A4	C3	C3
3	B1	B1	B3
4	A4	A4	C4
5	B4	B4	C4
6	C4	C4	C4
7	A3.5	A3.5	A4
8	A3.5	A3.5	A3.5
9	A4	A4	C2
10	C3	C3	C4
11	B1	B1	B3
12	A3.5	A4	A4

13	D3	D3	D4
14	B4	B4	C4
15	C2	C2	C3
16	B2	B2	B3
17	C2	C3	C4
18	A3	A3	A4
19	B2	B2	B3
20	C2	C2	C3
Cochran's Q test	Cochran's Q = 31.000, df = 2, P = 0.000 (<0.05), Significant		
McNemar test (Pairwise comparison with Bonferroni correction)	Baseline (T ₀) and After 6 months (T ₁): P = 0.250 (>0.017), not significant Baseline (T ₀) and After 12 months (T ₁): P = 0.000 (<0.017), Significant After 6 months (T ₁) and After 12 months (T ₁): P = 0.000 (<0.017), Significant		

Table 4 shows tooth shade distribution (VITA) and shade stability of monolithic zirconia crowns in Group 3 (dual users) at different time points (baseline, 6 months, and 12 months). At 6 months, shade change from baseline was observed in 3 patients (15%), and by 12 months a total of 18 patients (90%) showed a shift to darker VITA shades, indicating marked progressive shade instability in this group. Cochran's Q test demonstrated a statistically significant difference in shade status across the three time points (Q = 31.000, df = 2, P < 0.05). McNemar tests with Bonferroni correction for pairwise comparison showed that shade change between baseline and 6 months was not statistically significant (P > 0.017), whereas changes from baseline to 12 months (P < 0.017) and from 6 to 12 months (P < 0.017) were statistically significant, confirming substantial additional shade darkening between 6 and 12 months in dual users.

Intra-group analysis using Cochran's Q test demonstrated statistically significant differences in shade stability over

time among smokers, smokeless tobacco users, and dual users (P < 0.05). Pairwise comparisons revealed significant differences between baseline and 12 months as well as between 6 and 12 months in all tobacco-user groups.

Inter-group comparison at 6 months did not reveal any statistically significant difference in shade stability among the groups (P = 0.238). However, at 12 months, a highly significant difference was observed among the groups ($\chi^2 = 39.768$, P < 0.001). Non-tobacco users maintained complete shade stability, whereas all tobacco-user groups demonstrated progressive discoloration. No significant difference was observed among smokers, smokeless tobacco users, and dual users, suggesting that cumulative tobacco exposure rather than the specific form of tobacco primarily influenced shade instability. (Table 5 and 6)

Table 5: Inter-group comparison of shade stability of monolithic zirconia crowns from baseline to 6-months follow-up.

Groups	Shade Stability		Total n (%)
	Yes n (%)	No n (%)	
Group 0 (Non-tobacco users)	20 (100.00)	00 (0.00)	20 (100.00)
Group 1 (Smokers)	20 (100.00)	00 (0.00)	20 (100.00)
Group 2 (Smokeless tobacco users)	16 (80.00)	04 (20.00)	20 (100.00)
Group 3 (Dual users)	17 (85.00)	03 (15.00)	20 (100.00)
Chi-square test	Yates' $\chi^2 = 4.227$, df = 3, P = 0.238 (> 0.05), Not significant		

Table 5 present an inter-group comparison of shade stability of monolithic zirconia crowns from baseline to 6-month follow-up across the four study groups. All 20 patients (100%) in Group 0 (non-tobacco users) and all 20 patients (100%) in Group 1 (smokers) demonstrated shade stability at 6 months, whereas in Group 2 (smokeless tobacco users) 16 patients (80.00%) maintained shade stability with 4 patients (20.00%)

showing shade change, and in Group 3 (dual users) 17 patients (85.00%) maintained shade stability with 3 patients (15.00%) showing shade change. Yates' chi-square test revealed no statistically significant difference in shade stability between the study groups at the 6-months follow-up ($\chi^2 = 4.227$, df = 3, P > 0.05).

Table 6: Inter-group comparison of shade stability of monolithic zirconia crowns from baseline to 12-months follow-up.

Groups	Shade Stability		Total n (%)
	Yes n (%)	No n (%)	
Group 0 (Non-tobacco users)	20 (100.00)	00 (0.00)	20 (100.00)
Group 1 (Smokers)	06 (30.00)	14 (70.00)	20 (100.00)
Group 2 (Smokeless tobacco users)	05 (25.00)	15 (75.00)	20 (100.00)
Group 3 (Dual users)	02 (10.00)	18 (90.00)	20 (100.00)
Chi-square test (Overall)	$\chi^2 = 39.768$, df = 3, P = 0.000 (<0.05), Significant		
Chi-square test (Pairwise comparison with Bonferroni correction)	Non-tobacco user and Smokers: $\chi^2 = 21.538$, df = 1, P = 0.000 (<0.008), Significant Non-tobacco user and Smokeless tobacco users: $\chi^2 = 24.000$, df = 1, P = 0.000 (<0.008), Significant Non-tobacco user and Dual users: $\chi^2 = 32.727$, df = 1, P = 0.000 (<0.008), Significant Smokers and Smokeless tobacco users: $\chi^2 = 0.125$, df = 1, P = 0.724 (>0.008), Not significant Smokers and Dual users: Yates' $\chi^2 = 1.406$, df = 1, P = 0.236 (>0.008), Not significant Smokeless tobacco users and Dual users: Yates' $\chi^2 = 0.693$, df = 1, P = 0.405 (>0.008), Not significant		

Table 6 present an inter-group comparison of shade stability of monolithic zirconia crowns from baseline to

12-months follow-up across the four study groups. At 12 months, all 20 patients (100%) in Group 0 (non-tobacco

users) maintained complete shade stability, whereas Group 1 (smokers) showed 6 patients (30.00%) with shade stability and 14 patients (70.00%) with shade change, Group 2 (smokeless tobacco users) had 5 patients (25.00%) with shade stability and 15 patients (75.00%) with shade change, and Group 3 (dual users) showed the poorest outcome with only 2 patients (10.00%) maintaining shade stability and 18 patients (90.00%) exhibiting shade change.

Overall chi-square test revealed a highly statistically significant difference in shade stability between the study groups ($\chi^2 = 39.768$, $df = 3$, $P < 0.05$). Pairwise comparisons with Bonferroni correction demonstrated that Group 0 (non-tobacco users) differed significantly from all other groups: Group 1 smokers ($\chi^2 = 21.538$, $P < 0.008$), Group 2 smokeless tobacco users ($\chi^2 = 24.000$, $P < 0.008$), and Group 3 dual users ($\chi^2 = 32.727$, $P < 0.008$). However, among the tobacco user groups, no significant differences were found between Group 1 and Group 2 ($\chi^2 = 0.125$, $P > 0.008$), between Group 1 and Group 3 ($\chi^2 = 1.406$, $P > 0.008$), or between Group 2 and Group 3 ($\chi^2 = 0.693$, $P > 0.008$), suggesting that all tobacco-related exposures similarly compromise shade stability.

Conclusion

Monolithic zirconia crowns demonstrated excellent short-term shade stability across all study groups at the 6-month evaluation. However, prolonged tobacco exposure significantly compromised long-term esthetic outcomes, with progressive discoloration observed at 12 months among smokers, smokeless tobacco users, and dual users. Non-tobacco users maintained complete shade stability throughout the study period.

The findings indicate that shade instability of monolithic zirconia restorations is primarily influenced by cumulative tobacco exposure over time rather than the

specific form of tobacco consumption. Dual users exhibited the greatest degree of discoloration, highlighting the additive effect of combined smoking and smokeless tobacco habits. Tobacco use should therefore be considered an important prognostic factor during treatment planning and patient counseling regarding the long-term esthetic performance of monolithic zirconia restorations.

Clinical Implications

Although monolithic zirconia restorations exhibit favorable initial shade stability, prolonged tobacco exposure adversely affects their long-term esthetic performance. Clinicians should consider tobacco history during treatment planning, material selection, and informed consent procedures. Patients should also be educated regarding the possibility of discoloration and the importance of regular professional maintenance, polishing, oral hygiene practices, and tobacco cessation to preserve long-term esthetic outcomes.

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