Polymethyl methacrylate (PMMA) has been long in use for the fabrication of interim restorations. Although this material has provided satisfactory interim restorations in regard to esthetics and function, it has been accompanied with drawbacks such as heat generation, shrinkage, excess monomer, and color changes. In the past few decades, several other materials have come into usage. These materials have been developed to overcome the limitations of PMMA. In this study, we aimed to compare the color stability and the marginal integrity of four different interim crown materials.

**Objective:** To compare the color stability and marginal integrity of four different interim crown materials.**

**Materials and Methods:** An ivorine right maxillary central incisor was prepared for a full coverage all-ceramic restoration. A total of 36 specimens in the form of crowns were fabricated on the master die using four different materials (n = 9); Polymethyl methacrylate (PMMA) resin (TrimPLUS), PMMA computer-aided design, and computer-aided manufacturing (CAD-CAM) blocks (Ceramill TEMP), cold cure bis-acryl resin (Success CD), and bis-acryl resin dual-cure composite (TempSpan). Color change \( \Delta E \) for each sample was calculated by measuring its color as Commission Internationale de l’Eclairage L*, a*, b* with a spectrophotometer before and after immersing in a concentrated tea solution for 7 days. Marginal gap was measured at four reference points using stereomicroscope at \( \times 40 \). One-way ANOVA and the Tukey multiple comparisons test were used to determine any statistically significant difference between the four groups, (\( \alpha = 0.05 \)).

**Results:** Success CD showed significantly the greatest color change (7.7) among all the tested materials, while no significant difference was found between the other three materials. TempSpan showed significantly the highest marginal gap formation (430.15 \( \mu m \)), while no significant difference was found between the three other materials.

**Conclusions:** Bis-acryl resin composite materials demonstrated clinically noticeable change in color while PMMA materials demonstrated superior color stability. Dual cure interim materials exhibited significantly higher marginal discrepancy in comparison to PMMA and cold cure bis-acryl resin materials. CAD-CAM PMMA material exhibited the best color stability and marginal integrity.

**Key words:** Color stability, interim restorations, marginal fit

**INTRODUCTION**

Interim restorations play an important role in the success of dental treatment. They are essential to provide protection for dentin, restore esthetic and function, maintain positional stability, and promote gingival health. Although interim restorations are used for limited period, they still have to meet certain biologic, mechanical, and esthetic requirements to achieve these functions. [1]
include ethylmethacrylate, vinylmethacrylate, and butylmethacrylate, bis-acrylics (bisphenol A-glycidyl methacrylate and urethane dimethacrylate). \[3\]

Recently, computer-aided design and computer-aided manufacturing (CAD-CAM) technology have been utilized to fabricate interim restorations. Crosslinked PMMA blocks which have been previously polymerized are milled to produce interim restorations of better strength as well as homogeneity. Unlike conventional PMMA materials, PMMA blocks do not undergo polymerization shrinkage or have excess monomer as they are fully polymerized before milling. Moreover, studies have suggested superior physical and mechanical properties of this material and promoted its use for long-term interim restorations. \[4,5\]

Materials used for the fabrication of interim restorations varies greatly in their physical and mechanical properties such as stains resistance, dimensional stability, polishability, strength, surface hardness, and biocompatibility. \[6-10\] Yet no material is superior in all aspects and the restorative dentist should make the assessment of these materials’ advantages and disadvantages to decide which to use. \[11\]

The current study aimed to compare four different materials used to fabricate interim restorations in terms of their marginal integrity and color stability.

### MATERIALS AND METHODS

The study was registered and approved by the Institutional Review Board of Riyadh Colleges of Dentistry and Pharmacy (FUGRP/2012/5).

**Preparation of samples**

An ivorine right maxillary incisor was prepared for a full coverage all-ceramic restoration with a heavy chamfer margin. Four points were engraved at a distance of 1 mm below the facial, lingual, mesial, and distal margins \[12\] [Figure 1].

A total of 36 specimens in the form of crowns were fabricated on the master die using four different interim materials.

The samples were divided according to the material used into four groups of nine specimens in each group \(n = 9\) [Table 1].

For each interim crown in group PM, BC, and DC, the material was mixed and cured according to its manufacturer instructions. For group PMCAD, an impression for the master die was made and the working die was scanned. Crowns were designed and milled using Ceramill Mind software and Ceramill Motion Milling Machine (Amann Girrbach, Austria). Specimens of all groups were then finished and polished according to manufacturers’ instructions. All specimens were then stored in a light-protected container until ready for testing.

### Testing

**Marginal adaptation**

Crowns were fitted on the master die and tested for marginal adaptation using stereomicroscope at \(\times 40\) magnification (Nikon Stereoscopic Microscope, SMZ1000), and photographed (Nikon Digital Camera, DXM1200F). At each of the four engraved reference points, the vertical marginal gap between the finish line and the crown margin was measured to the nearest 0.01 \(\mu m\) [Figure 2]. The average marginal gap was calculated and tabulated for each sample.

| Group      | Material type                          | Brand      | Manufacture       |
|------------|----------------------------------------|------------|-------------------|
| Group PM   | Polymethyl methacrylate                | Trimplus   | Bosworth, USA     |
| Group PMCAD| Polymethyl methacrylate CAD-CAM blocks | Ceramill TEMP | Hersteller, Germany |
| Group BC   | Bis-acryl composite resin              | Success CD | Promedics, Germany |
| Group DC   | Dual cure composite resin              | Temspan    | Pentron, USA      |

CA-CAM: Computer-aided design and computer-aided manufacturing
Color stability test
Baseline color measurements
Baseline color measurements for all specimens were done using spectrophotometer (Color-Eye 7000A, X-Rite Europe GmbH, Switzerland). The measurements were established in mathematic coordinates referred to the international color space Commission Internationale de l’Eclairage L* a* b*. For each sample, three readings at the labial surface were taken. The average L*, a*, and b* values for the three readings were calculated and tabulated as the baseline color measurements.

Staining solution
Specimens were immersed in a high concentration tea solution (Lipton, Unilever Gulf FZE, UAE) at 37°C. Temperature was controlled using a thermostatically controlled incubator. The solution was constantly changed every 2 days. After 7 days of immersing crowns in the tea solution, the specimens were rinsed with distilled water, brushed with Aquafresh, soft brush (GlaxoSmithKline, the UK), and blotted dry with tissue paper before the second color measurement.

Poststain color measurements
The color of the specimens was measured again using the spectrophotometer and tabulated as described previously. The calculation of the color change ΔE* between the two color positions (after storage and baseline) was calculated according to the following formula: ΔE* = ((L2* − L1*)2 + (a2* − a1*)2 + (b2* − b1*)2)1/2.[13]

Color change >3.3 was considered clinically unacceptable.[14]

Statistical analysis
The measurements were analyzed using one-way ANOVA with a Tukey post hoc multiple comparison to determine any statistically significant difference in color change and marginal gap between the four materials. Analysis was done using the Statistical Package for Social Sciences (SPSS version 17.0 SPSS Inc, Chicago, USA). The level of statistical significance was set at P < 0.05.

RESULTS

Color stability
The mean color change ΔE values of the four materials are shown in Figure 3. TempSpan and Success CD are the only two materials that exhibited clinically noticeable color change (ΔE >3.3). Analysis of results showed significant difference between the four materials (P = 0.00). Success CD showed significantly the greatest color change among all the tested materials, while no significant difference was found between the other three materials [Table 2].

Marginal adaptation
The mean gap formation for each group is shown in Figure 4. Analysis of results showed significant difference between the four materials (P = 0.00).

Table 2: One-way ANOVA comparison for the color change between groups

| Material (I)      | Material (J)      | Mean difference | SE    | Significant |
|-------------------|-------------------|-----------------|-------|-------------|
| TrimPLUS          | Ceramill TEMP     | 0.52766         | 1.11133| 0.964       |
| Success CD        | TrimPLUS          | −5.37315*       | 1.11133| 0.000       |
| TempSpan          | TrimPLUS          | −1.51732        | 1.11133| 0.530       |
| Ceramill TEMP     | TrimPLUS          | −0.52766        | 1.11133| 0.964       |
| Success CD        | TrimPLUS          | −5.90081*       | 1.11133| 0.000       |
| TempSpan          | TrimPLUS          | −2.04498        | 1.11133| 0.274       |
| Success CD        | Ceramill TEMP     | 5.37315*        | 1.11133| 0.000       |
| TempSpan          | Ceramill TEMP     | 5.90081*        | 1.11133| 0.000       |
| TempSpan          | Success CD        | 3.85583*        | 1.11133| 0.008       |
| TrimPLUS          | Success CD        | 1.51732         | 1.11133| 0.530       |
| Ceramill TEMP     | Success CD        | 2.04498         | 1.11133| 0.274       |
| TempSpan          | Success CD        | −3.85583*       | 1.11133| 0.008       |

*p < 0.05. SE: Standard error
TempSpan showed significantly the highest marginal gap formation among the tested materials, while no significant difference was found between the three other materials [Table 3].

**DISCUSSION**

Despite being used for limited time, color stability of interim crowns is a concern, particularly when the interim restoration is in the esthetic zone, and must be worn for extended periods of time. Moreover, an interim restoration needs to seal and insulate the prepared tooth from the oral environment, thereby protecting the underlying pulp from insult and injury and the prepared dentin from recurrent decay. Yet, many studies have reported significant color changes and marginal discrepancy of interim restorations made of different materials. [5,8,9] Unlike permanent restorations, interim restorations are usually used for limited times. Thus, in the current study, samples were immersed in high concentration tea solution for 1 week. This method does not exactly reflect the clinical reality. However, similar protocol to evaluate color stability of interim restorations was adopted in previous studies and was considered adequate. [9]

Various studies have reported different thresholds of color difference values ranged from 1 to 3.7 above which the color change is perceptible by the human eye. [14] In the present study, a color change ($\Delta E^*$) >3.3 was considered visually perceptible as well as clinically unacceptable. Both bis-acryl methacrylate based resins in this study; TempSpan and Success CD demonstrated visually perceptible and clinically unacceptable color change (3.88 and 7.74, respectively). Moreover, the auto-cured bis-acryl (Success CD) crowns showed significantly the highest color change. Those results were in agreement with previous studies. [8-10] Proprietary variations in chemistry, such as size distribution of the PMMA particles, polarity of the monomers, pigment stability, and efficiency of the initiator system for interim resins may lead to differing degrees of polymerization, water sorption, and consequently, color stability. [8]

As with permanent restorations, marginal adaptation of interim restorations is detrimental for the success of treatment and maintenance of teeth and gingival health. [1] The results of the present studies showed that dual cured bis-acryl interim material (TempSpan) demonstrated significantly the highest mean marginal gap (430.15 $\mu$m) when compared to the other groups. This was in agreement with Givens et al. who suggested that that the majority of gap formation occurs during the auto-cure phase of polymerization of dual-cured materials. [9]

In this study, the machined CAD-CAM material demonstrated the lowest mean color change (1.84) and lowest mean marginal gap (49.76 $\mu$m). This can be attributed to the industrially optimized conditions under which the polymerization of this material happens so it has no or minimal residual unreacted monomers and lower polymerization shrinkage. This supports the recommendation of similar studies to use machined CAD-CAM resin blocks for the fabrication of long-term interim restorations. [4,5]

**CONCLUSIONS**

Under the conditions of this study, the following can be concluded:
1. The bis-acryl resin composite materials demonstrated clinically noticeable change in color while PMMA materials demonstrated superior color stability
2. Dual cure interim materials exhibited significantly higher marginal discrepancy in comparison to
PMMA and cold cure bis-acrylic resin materials
3. CAD-CAM PMMA material exhibited the best color stability and marginal integrity.

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Conflicts of interest
There are no conflicts of interest.

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