Effect of Miswak Derivatives on Color Changes and Mechanical Properties of Polymer-Based Computer-Aided Design and Computer-Aided Manufactured (CAD/CAM) Dental Ceramic Materials

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Background:
Miswak is a form of chewing stick used to clean teeth in different parts of the world, including Saudi Arabia. We present a description of the effects of miswak derivatives, namely toothpaste, mouthwash, and brushing sticks, on the mean color changes ($\Delta E_{00}$), compressive fracture resistance values, and fracture modes of polymer-based computer-aided design (CAD) and computer-aided manufactured (CAM) prosthetic materials.

Material/Methods:
Eighty-one rectangular-shaped samples were prepared from lithium disilicate glass-ceramic (IPS e.max CAD), zirconia-reinforced lithium silicate (Vita Suprinity), and monochromatic tooth-colored feldspar (Vitablocs Mark II) CAD/CAM ceramics. The color parameters were recorded using spectrophotometer before and after exposing the specimens to the different miswak oral hygiene derivatives for 15 days. Compressive fracture resistance values and fracture types were also assessed, and statistical analysis was performed.

Results:
Vita Suprinity and Vitablocs Mark II miswak sticks had the highest $\Delta E_{00}$ values. Moreover, miswak mouthwash had the lowest $\Delta E_{00}$ values, with significant differences among groups. IPS e.max CAD miswak sticks had the highest mean values of compressive fracture. Vitablocs Mark II had the lowest values for mouthwash and toothpaste. Significant differences were found within the IPS e.max CAD group. Reparable fractures were found in IPS e.max CAD, while semi-reparable fractures were seen in other groups.

Conclusions:
Most $\Delta E_{00}$ values were within the acceptable clinical range, with IPS e.max CAD showing superior color stability. The mouthwash group showed minimal $\Delta E_{00}$, IPS e.max CAD had the highest mean compressive fracture resistance values with reparable fracture types.

Keywords: Color • Mouthwashes • Toothpastes

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Background

Aesthetics and biocompatibility are the primary reasons for the current extensive use of dental ceramic restorations. Over time, the color and structure of these computer-aided design (CAD) and computer-aided manufacturing (CAM) milled glass ceramic materials can be altered by complex processes in the oral cavity [1]. In the last decade, there has been an increased demand for aesthetic restorations with color stability for better appearance, which can be provided by zirconia types of ceramic [2,3]. CAD/CAM materials have been an integral part of dentistry over the last 3 decades. This system is used in dental laboratories and clinics and is a daily practice for constructions of partial coverings as well as crowns, fixed partial dentures, and implant abutments [1,3,4].

Lithium disilicate glass ceramic (IPS e.max CAD), zirconia-reinforced lithium silicate (Vita Suprinity), and monochromatic tooth-colored feldspar (Vitablocs Mark II) ceramic restorative materials are ceramics used in dentistry and are characterized by qualities of strength, brittleness, transparency, and hardness. Their chief benefits comprise biocompatibility, low plaque adhesion susceptibility, and color stability [5,6]. In addition, IPS e.max CAD and Vitablocs Mark II have high wear resistance [5]. Zirconia as a ceramic material has a unique microstructure, grain size, and distribution of grains, resulting in a significant effect on its clinical performance and survivability [1].

Salvadora persica (Miswak) has long been used to maintain oral hygiene and is part of the Islamic oral health heritage. Oral bacteria populations and plaque scores are decreased with the use of miswak, according to Jasma et al [7]. Miswak sticks are usually pencil-sized, 10 to 25 cm long, and 0.5 to 1.5 cm in diameter [8]. They are typically chewed on one end until the end is frayed and then used like a conventional brush to clean teeth with dual action: mechanical and therapeutic. Miswak is available commercially as a brushing stick, toothpaste, and mouthwash [9]. Shetti et al found that miswak extract reduced gingival inflammation and plaque scores, indicating that it can be used as a chemical plaque management agent and to avoid discoloration of surfaces of teeth exposed in the oral cavity [10]. Moreover, compared with toothbrushes, miswak stick extract had a substantial effect on the microbial count of cariogenic bacteria in an in vivo investigation by Bhat et al [11]. A study by Varma et al showed that brushing with miswak-based toothpaste significantly reduced plaque scores compared with those of tea tree oil-based toothpaste [12,13].

Salvadora persica sticks have been suggested by the World Health Organization (WHO) as an excellent oral health tool, owing to the mechanical action of the softwood fibers and the therapeutic action of its chemical contents [14]. Chinese medicine included mouth rinses to treat gingival disorders as early as 2700 BC. Mouth rinses with active therapeutic agents have recently been recommended as a daily oral healthcare therapy to manage dental plaque and minimize tooth discoloration [15]. Along with the practice of daily mechanical procedures, the use of mouthwash is the safest and most feasible and effective way to achieve an acceptable antimicrobial habitat [16]. To keep tooth structure healthy, both physically and chemically, various toothpastes have been considered [17,18]. Paste dentifrices use abrasives [16], surfactants, polymers, calcium chelators, and enzymes to prevent or remove stains. In toothpaste, abrasives are the main cleaning agents [19,20].

The use of chemical plaque management agents in patients prone to periodontal disease and dental caries, especially patients with fixed prosthodontics, can cause undesirable effects, such as prosthetic staining [21]. The perceptible and clinically acceptable thresholds of the mean color change (ΔE*ab) values is considered to be between 2.8 and 4.2 units [22,23]. A group of studies evaluated color change using the Vita Easyshade spectrophotometer, according to the Commission Internationale de l’Eclaireage (CIELab) system [21,24,25]. Derafshi et al found mean ΔE*ab values of 0.82 and 0.64 for zirconia samples after immersion in chlorhexidine and Listerine mouthwashes, respectively [21]. Soygun et al documented mean ΔE*ab values for IPS e.max CAD immersed in Listerine, Klorhex, and Tantum Verde as 0.46±0.27, 0.49±0.23, and 0.48±0.13, respectively, while the values of the Lava Ultimate CAD were 1.31±0.58, 0.64±0.36, and 2.54±0.32, respectively, for the same mouthwash brands [24]. After staining lithium disilicate in coffee, tea, and chlorhexidine gluconate, Haralur et al found ΔE*ab values of 1.78, 2.241, and 1.58, respectively. Furthermore, monolithic zirconia ΔE*ab values stained with the same products were 5.60, 5.19, and 4.86, respectively, which were slightly higher than the clinically acceptable range [25].

Reports in the literature are scarce on miswak products and their influence on prosthetic materials, and no studies were found comparing the effect of different miswak derivatives on the color changes and mechanical properties of CAD/CAM restorative materials. Therefore, the aim of this present in vitro study was to assess and compare the effect of miswak derivatives (miswak toothpaste, miswak mouthwash, and miswak as brushing sticks) as oral hygiene aids on the color stability of IPS e.max CAD, Vita Suprinity, and Vitablocs Mark II ceramic restorative materials. Our first null hypothesis was that there would be no significant differences in the mean ΔE*ab values of different CAD/CAM ceramic restorative materials after using the 3 different oral hygiene aids (miswak derivatives). The second null hypothesis was that there would be no significant differences between the values of compressive fracture resistance values and failure types among the tested materials after using miswak products.
Material and Methods

Sample Size and Study Design

Ethical approval was given by the Scientific Committee, College of Dentistry (CODJU-2016I). The sample size for each group (n=27) was computed using the data from published studies on ΔEs, with values of α=0.05 and power (1- β)=85% [24,25]. The design of this in vitro study included different CAD/CAM ceramic samples (81 overall) and compared the effects of miswak and its derivatives on color stability of CAD/CAM ceramic materials after 15 days of application [21,24,25].

Sample Grouping and Preparation

A total of 81 glazed samples were prepared, with 27 of each of the 3 CAD/CAM ceramic restorative materials: IPS e.max CAD (Ivoclar Vivadent, Liechtenstein), Vita Suprinity (Vita Zahnfabrik, H. Rauter Bad Säckingen, Germany), and Vitablocs Mark II (Vita Zahnfabrik, H. Rauter Bad Säckingen, Germany). All samples were manufactured using a CAD/CAM machine (Amann Girrbach, Germany). Blocks of material were installed on a milling machine (CAM) to produce 27 blocks from each material with a uniform and standardized dimensional size (16×12 mm) and thickness (2.1 mm) for each restorative material, following the manufacturer’s instructions. The samples were finished and smoothed with 300 to 800 grit silicon carbide paper (Dentsply Prosthetics Brasseler USA). After cleaning with distilled water in an ultrasonic machine, the samples were washed with isopropanol to remove any grease residue and were then dried with compressed air. The Vita Suprinity and Vitablocs Mark II samples were sintered for 2 h at 1550°C in a furnace (Programat P310; Ivoclar Vivadent AG), while the lithium disilicate glass ceramic (IPS e.max CAD; Ivoclar Vivadent AG) blocks were crystallized, as recommended by the manufacturer. All samples of each group were further divided into 3 equal subgroups of 9 each according to the miswak oral hygiene aid type.

Color Measurements

Before being exposed to the oral hygiene aids, color measurements were done for all the samples on a gray background by a single operator (Al M. M.) using a portable spectrophotometer probe (Vita Easylshade III, Vita Zahnfabrik H. Rauter GmbH, Bad Säckingen, Germany). A putty index with a 5-mm hole in the middle was made around the block to standardize the visible ceramic surface area during color testing. The edges of the hole were well-shaped and precise [25]. Three color parameters were evaluated: L*, a*, and b*, where L* denotes lightness, in which the higher the L value, the greater the lightness; a* denotes red color on positive values and green color on negative values; and b* denotes yellow color on positive values and blue color on negative values. The parameters were recorded for each CAD/CAM ceramic material using the CIELab color system, which gave the arithmetical values for the 3D color measurements [22-26,27]. The baseline color parameters (L1, a1, and b1) were measured 3 times for each specimen at the same time of day, and the average was used to represent the color coordinates before the application of miswak derivatives and thermocycling.

Application of Miswak Derivatives Oral Hygiene Aids

After the baseline measurements, the specimens of the 3 groups were exposed to the 3 miswak derivatives (or oral hygiene aids groups). For the miswak toothpaste group, minty fresh Aloe Dent miswak (Optima Naturals, Kingdom of Saudi Arabia) was used. Each brushing period (2 times a day, each for 30 s) required 0.25 g of toothpaste, which was diluted in a 1:3 ratio with water. Brushing was accomplished by using a circular motion with a toothbrush, followed by rinsing the samples under running water. The artificial saliva was renewed after the tooth-brushing procedure, and the samples were maintained in the artificial saliva in a dark glass container at room temperature for the duration of the testing period [28]. The miswak mouthwash used was the commonly used alcohol-free mouthwash Listerine Miswak milder taste (Listerine; Johnson & Johnson, Saudi Arabia; pH=4.2). Each sample was subjected to 20 mL mouthwash at 37°C for 15 days to simulate everyday use [29,30], which is equivalent to 1 year of mouthwash use when rinsed twice a day for 30 s each time. Every 12 h, the mouthwash solution was replaced [31]. The miswak stick with fresh fiber, usually soft, was rubbed on each sample for 30 s in a circular motion to cover the whole surface 2 times per day. The used end of the stick was removed daily to get the benefit of fresh components of miswak. One operator (Al M. M.) prepared the samples of the 3 CAD/CAM ceramic materials and applied the 3 oral hygiene aids. After the baseline measurements of the samples and during miswak derivative application, samples were placed in a plastic container with a special mold prepared from rubber base materials.

Thermocycling and Second Color Parameter Measurements

After using miswak oral hygiene aids for 15 days, the samples were removed from the distilled water of the ageing machine and thermocycling processing was performed in 5°C cold water and then in 55°C hot water for a total number of 5000 cycles, followed by rinsing with distilled water and blot drying with tissue paper. Second recordings of color parameter measurements were done following the same protocol and were registered as posttreatment readings (L2, a2, and b2). The mean ΔEs, values were calculated by the equation: ΔEs,(=,(L2-L1)+2(Da)+2(Δb))×½, where L* is the difference of L*, Δa is the variation of a*, and Δb* is the variation of b* [20-22].
As noted in prior investigations, an $\Delta E_{00}$ value was connected with and equivalent to a perceptible threshold of $\Delta$2.8 and a clinically acceptable threshold of $\Delta$4.2 [26,27].

**Application of Compressive Forces**

The compressive fracture resistance values of the samples were determined using computer-controlled universal testing equipment (Zwick Z010/TN2A, Ulm, Germany) with an across-head speed of 0.5 mm/min and a 4 mm diameter rod, as suggested in ISO standard 6872, in air at room temperature. To distribute fracture forces and ensure a broad uniform contact between the sample and the force loading 3-mm radius stainless steel hemispherical tip, a 0.5-mm thermoplastic resin tape was applied to the center of each CAD/CAM sample surface. The maximum force load of each sample was automatically recorded in Newton (N) by a computer connected to the loading equipment as force was applied down the longitudinal axis at the center of each sample until fracture [32-34]. Compressive fracture resistance value measurements for all samples were done in the Biomaterial Laboratory, College of Dentistry King Saud University, Riyadh, Saudi Arabia.

**Failure Type Definition**

The shape, number of fragments following fractures, and ratio between each piece measurement and the original shape were recorded for each sample. The types of fracture were classified according to the following criteria (Table 1):

Type 1: (Reparable) in which the specimen is broken into 2 halves, where each half would have 50% of the measurement of the original shape.

Type 2: (Semi-reparable) in which the specimen is broken into 3 to 4 pieces, where each piece would measure between 20% to 35% of the measurement of the original shape.

Type 3: (Non-reparable) in which the specimen is broken into more than 4 pieces, where each piece would measure less than 20% of the original shape [34].

**Statistical Analysis**

The mean and standard deviation (SD) of the $\Delta E_{00}$ values for various CAD/CAM ceramic restorative samples were calculated after the application of different miswak derivatives (15 days) and thermocycling. SPSS version 22.0 was used for the statistical analysis (IBM Corp, Armonk, NY, USA). The mean and SD of compressive fracture resistance values, as well as the fracture type, were recorded for each of the tested groups. Kruskal-Wallis and Mann-Whitney post hoc tests were used to check the significance between and within the groups. The significance level was $P=0.05$.

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**Table 1. Fracture types and definitions.**

| Fracture type                  | Definition                                           |
|-------------------------------|------------------------------------------------------|
| Type 1 – Uniform fracture passing at the middle | Specimens fractured into 2 equal sizes, reparable fracture |
| Type 2 – Mixed fracture       | Specimens fractured into 3 to 4 pieces, semi-reparable fracture |
| Type 3 – Complicated fracture | Specimens fractured into more than 4 pieces, non-reparable fracture |

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**Table 2. Mean $\Delta L^*$, $\Delta a^*$, $\Delta b^*$, and $\Delta E_{00}$ values after oral hygiene aids application for all-ceramic restorations.**

| Ceramic type     | Oral aid type | $\Delta L^*$ | $\Delta a^*$ | $\Delta b^*$ | $\Delta E_{00}$ |
|------------------|---------------|--------------|--------------|--------------|-----------------|
| IPS e.max CAD    | Miswak toothpaste | -2.41        | -0.34        | -0.81        | 3.56            |
|                  | Miswak mouthwash | -0.69        | -0.88        | 1.10         | 0.47            |
|                  | Miswak stick    | -1.51        | 0.88         | -1.30        | 1.93            |
| Vita Suprinity   | Miswak toothpaste | -0.91        | -0.83        | -0.10        | 1.75            |
|                  | Miswak mouthwash | 0.85         | -0.40        | 0.03         | 0.48            |
|                  | Miswak stick    | -2.45        | -0.35        | -1.11        | 3.91            |
| Vitablocs Mark II| Miswak toothpaste | -1.90        | -0.36        | -1.43        | 3.69            |
|                  | Miswak mouthwash | -0.87        | 0.34         | -1.71        | 2.92            |
|                  | Miswak stick    | -2.14        | -0.24        | -1.35        | 3.73            |

$\Delta L^*$ – mean L (lightness); $\Delta a^*$ – mean a (green-red); $\Delta b$ – mean b (blue-yellow); $\Delta E_{00}$ – mean color change.
The mean $D_{L^*}$, $D_{a^*}$, $D_{b^*}$ values and the $D_{E_00}$ for all the CAD/CAM material tested samples after different oral hygiene aid applications for 15 days are summarized in Table 2. Highest changes in $D_{E_00}$ value were recorded in Vita Suprinity and Vitablocs Mark II for miswak sticks, followed by toothpaste samples with Vitablocs Mark II and IPS e. max CAD ceramic types. The mouthwash group recorded the lowest $D_{E_00}$ values in Vita Suprinity and IPS e. max CAD samples, with almost the same value. Overall, the $D_{E_00}$ for miswak stick groups had the highest values, while the mouthwash group had the lowest values among the 3 tested ceramics, compared with other oral hygiene aids. IPS e.max CAD showed less color changes than the other ceramics, and the lowest value was for the miswak mouthwash group (Figure 1).

Table 3 summarizes the results of the Kruskal-Wallis analysis of $D_{E_00}$ between different all-ceramic restorations after application of different miswak derivatives.

| Oral aids type     | Ceramic type       | Mean rank | Chi-Square | Df | P     |
|--------------------|--------------------|-----------|------------|----|-------|
| Miswak toothpaste  | IPS e.max CAD      | 17.75     | 4.192      | 2  | 0.123 |
|                    | Vita Suprinity     | 10.85     |            |    |       |
|                    | Vitablocs Mark II  | 17.90     |            |    |       |
| Miswak mouthwash   | IPS e.max CAD      | 12.85     | 20.159     | 2  | 0.001*|
|                    | Vita Suprinity     | 8.30      |            |    |       |
|                    | Vitablocs Mark II  | 25.35     |            |    |       |
| Miswak stick       | IPS e.max CAD      | 11.00     | 3.931      | 2  | 0.140 |
|                    | Vita Suprinity     | 17.95     |            |    |       |
|                    | Vitablocks Mark II | 17.65     |            |    |       |

Df – degrees of freedom. * The mean difference is significant at $P \leq 0.05$.  

Results

The mean $D_{L^*}$, $D_{a^*}$, $D_{b^*}$ values and the $D_{E_00}$ for all the CAD/CAM material tested samples after different oral hygiene aid applications for 15 days are summarized in Table 2. Highest changes in $D_{E_00}$ value were recorded in Vita Suprinity and Vitablocs Mark II for miswak sticks, followed by toothpaste samples with Vitablocs Mark II and IPS e. max CAD ceramic types. The mouthwash group recorded the lowest $D_{E_00}$ values in Vita Suprinity and IPS e. max CAD samples, with almost the same value. Overall, the $D_{E_00}$ for miswak stick groups had the highest values, while the mouthwash group had the lowest values among the 3 tested ceramics, compared with other oral hygiene aids. IPS e.max CAD showed less color changes than the other ceramics, and the lowest value was for the miswak mouthwash group (Figure 1).

The mouthwash group had statistically significant differences between Vitablocs Mark II with IPS e.max and Vita Suprinity ($P \leq 0.001$ and 0.004), while there was no statistically significant difference between Vita Suprinity and IPS e.max. Also, there were no significant differences in the toothpaste and miswak stick oral aids (Table 4). Significant differences in CAD/CAM restorative materials, the interaction between various oral aids
measures, and the interaction between the CAD/CAM restorative materials and oral aid measures were found in the 2-way repeated measures ANOVA, with $P$ values $\leq 0.001$ and 0.03, respectively (Table 5).

The highest mean value and standard deviation of fracture resistance were recorded in the IPS e.max CAD group, and were highest in the miswak sticks group. Vitablocs Mark II had the lowest mean values in the mouthwash and toothpaste groups (Table 6). ANOVA showed no significant differences between

### Table 4. Mann-Whitney post hoc pairwise comparison between the $\Delta E_{00}$ recorded in different miswak derivative groups.

| Oral aid type        | Ceramic type  | IPS e. max | Vita Suprinity | Vitablocs Mark II |
|----------------------|---------------|------------|----------------|-------------------|
| Miswak toothpaste    | IPS e.max CAD | –          | 0.742          | 0.004*            |
|                      | Vita Suprinity| –          | 0.742          | –                 |
|                      | Vitablocs Mark II| –          | 0.004*          | –                 |
| Miswak mouthwash     | IPS e.max CAD | –          | 0.742          | 0.001*            |
|                      | Vita Suprinity| –          | 0.004*          | –                 |
|                      | Vitablocs Mark II| –          | 0.001*          | –                 |
| Miswak stick         | IPS e.max CAD | No significance | –          | –                 |
|                      | Vita Suprinity| –          | No significance | –                 |
|                      | Vitablocs Mark II| –          | No significance | –                 |

* The mean difference is significant at $P \leq 0.05$.

### Table 5. Two-way repeated measures ANOVA results for values of $\Delta E_{00}$ related to different ceramic restoration and measures of different oral hygiene aids.

| Source                             | Type III sum of squares | Df | Mean square | F     | P      |
|------------------------------------|-------------------------|-----|-------------|-------|--------|
| Ceramic types                      | 51.576                  | 2   | 25.788      | 6.249 | 0.001* |
| Oral aids types                    | 90.854                  | 2   | 45.427      | 11.009| 0.001* |
| Ceramic type X oral aids types     | 57.472                  | 4   | 14.368      | 3.482 | 0.03*  |
| Errors                             | 334.22                  | 81  | 4.126       |       |        |

Df – degrees of freedom. * Significant difference at $P \leq 0.05$.

### Table 6. Means and standard deviations of fracture resistance (N) of different ceramics with oral hygiene aids type.

| Ceramic type    | Oral hygiene aids type    | Fracture resistance (N) | Overall fracture resistance (Newton) | P   |
|-----------------|---------------------------|-------------------------|--------------------------------------|------|
| IPS e.max CAD   | Miswak toothpaste         | 836.58 (111.10)         | 829.21±101.79                       | 0.051|
|                 | Miswak mouthwash          | 771.80 (80.84)          |                                      |      |
|                 | Miswak stick              | 879.24 (113.42)         |                                      |      |
| Vita Suprinity  | Miswak toothpaste         | 346.64 (59.23)          | 340.63±55.93                        | 0.241|
|                 | Miswak mouthwash          | 331.27 (52.40)          |                                      |      |
|                 | Miswak stick              | 343.98 (54.54)          |                                      |      |
| Vitablocs Mark II | Miswak toothpaste      | 304.29 (18.01)          | 312.65±19.33                        | 0.198|
|                 | Miswak mouthwash          | 302.25 (11.75)          |                                      |      |
|                 | Miswak stick              | 331.40 (28.23)          |                                      |      |

* Significant difference at $P \leq 0.05$. 
groups, with \( P \) values of 0.051, 0.241, and 0.198, respectively. The Mann-Whitney post hoc test between the different ceramic groups and oral aid subgroups showed a statistically significant difference among the IPS e.max CAD group and toothpaste, mouthwash, and stick groups (\( P \leq 0.001 \)). Both Vita Suprinity and Vitablocs Mark II had no significant differences between those parameters and the oral aid types tested in relation to the values of fracture resistance (Table 7).

According to the definitions of the fracture types shown in Table 1, type 1 (reparable) fracture was recorded in almost 100% in IPS e.max CAD among all miswak derivatives but was not recorded in any of Vita Suprinity or Vitablocs Mark II groups. Type 2 fracture was predominant in 70% to 80% of all groups of Vita Suprinity and in 60% to 80% of all groups of Vitablocs Mark II. Type 3 fracture type was seen in 20% to 30% of all groups of Vita Suprinity and in 20% to 40% of all groups of Vitablocs Mark II for miswak oral hygiene aids (Figure 2), with no significant differences between and within the different groups.

**Discussion**

We evaluated the outcome of miswak derivatives (toothpaste, mouthwash, and stick) on the color stability of 3 different CAD/CAM ceramic materials: IPS e.max CAD, Vita Suprinity, and Vitablocs Mark II. To the best of our knowledge, this is the first study of its kind to be conducted. Overall, the mean \( \Delta E_{ab} \) values recorded were higher for Vitablocs Mark II than for the other materials tested. Meanwhile, the results of miswak mouthwash were significantly different between Vita Suprinity and the IPS e.max CAD and Vitablocs Mark II groups. In the present study, the recorded values of \( \Delta E_{ab} \) were parallel with all groups of Vitablocs Mark II for miswak oral hygiene aids (Figure 2), with no significant differences between and within the different groups.

**Table 7.** Mann-Whitney Post hoc pairwise comparison between ceramic type in relation to type of oral hygiene aid.

| Ceramic type       | Oral aid type   | Miswak toothpaste | Miswak mouthwash | Miswak sticks |
|--------------------|-----------------|-------------------|------------------|--------------|
| IPS e. max CAD     | Miswak toothpaste | –                 | 0.001*           | 0.001*       |
|                    | Miswak mouthwash | 0.001*            | –                | 0.001*       |
|                    | Miswak stick    | 0.001*            | 0.001*           | –            |
| Vita Suprinity     | Miswak toothpaste | –                 | No significance  |              |
|                    | Miswak mouthwash | No significance   | –                |              |
|                    | Miswak stick    |                   | –                |              |
| Vitablocs Mark II  | Miswak toothpaste | –                 | No significance  |              |
|                    | Miswak mouthwash | –                 | No significance  |              |
|                    | Miswak stick    | –                 | –                |              |

* Significant difference at \( P \leq 0.05 \).

**Figure 2.** Percentage of failure types of tested CAD/CAM ceramic materials after compressive force application.
the values documented by Derafshi et al [21] for zirconia and feldspathic ceramic, with those of Soygun et al [24] for IPS e.max CAD, and with those of Huaralur et al [25] for zirconia and IPS e.max CAD.

For many years, the shade guides were used to select tooth color for prostheses. This method was simple to use, even though it was erroneous and subjective. Later, systematic technologies that overcame the problems associated with visual guidance were presented. A spectrophotometer is a device that detects color differences and converts the data into numerical values. Accuracy, the capacity to explore the primary components of a series of spectra, and the ability to alter information to multiple color measuring schemes or classifications are some of the benefits of the spectrophotometer [22,25,26]. The device is inexpensive, easy to use, and frequently used by investigators [27,36]. On evaluation of performance, the ability of the Vita Easyslide color spectrophotometer was better than that of other spectrophotometers. It can be used during daily clinical dental practice and in the laboratory for dental research, with some limitations [36].

Clinical studies have suggested that the perceptible and clinically acceptable $\Delta E_{00}$ values should be between 2.8 and 4.2 units [22,23]. In the present study, the overall values of mean $\Delta E_{00}$ in all groups were within the acceptable clinical value range, except for the mouthwash group, with IPS e.max CAD (0.47) and Vita Suprinity (0.48). The first null hypothesis was partially rejected because a significant difference was detected among the miswak mouthwash group in 3 types of the tested ceramic materials. Many previous studies also mentioned that the $\Delta E_{00}$ values from 1 to 3.3 units are considered as clinically acceptable, while values greater than 3.3 are considered clinically unacceptable [22,25,37,38]. The values of $\Delta E_{00}$ recorded in the present study were similar with values recorded by Derafshi et al [21] for zirconia and feldspathic ceramic, with those of Soygun et al [24] for IPS e.max CAD, and those of Huaralur et al [25] for zirconia and IPS e.max CAD. Those studies used Listerine mouthwash as a cleaning/staining agent for the abovementioned CAD/CAM ceramics.

Miswak has played an important role in maintaining dental health. According to several studies, miswak has a number of qualities, including the ability to reduce teeth discoloration [13-15,23,39] and antibacterial, antifungal, antiviral, anticancer, and antioxidant properties [9].

Sasany et al [30] reported mean $\Delta E_{00}$ values of 2.2±0.9 and 1.2±0.9 for IPS e.max CAD and zirconia ceramic materials, respectively, after staining for 2 weeks with Listerine mouthwash, which were higher than the $\Delta E_{00}$ values observed in the present study. This could be due to the different compositions of mouthwashes used in the respective studies. The effectiveness of miswak toothpaste and mouthwash was higher than that of ordinary toothpaste in reducing the growth of cariogenic bacteria [39]. Toothbrushing can affect the color of ceramic-polymer material extrinsic characterization; nevertheless, this change can be clinically imperceptible to the human eye after around 6 years of brushing the ceramic-polymer materials [40]. The color of resin-based CAD/CAM blocks can vary over time, which can be a clinical concern. These color changes in the materials can be reduced below the perceptibility threshold level by utilizing whitening toothpastes [41]. A similar effect was obtained after coffee immersion for hybrid-ceramic CAD/CAM blocks (Ceramart A2-HT; GC, Tokyo, Japan) and a leucite reinforced feldspar ceramic after prophylactic paste polishing application [42]. Furthermore, even with proper homecare, the color stability of ceramic restorations is a clinical concern. When compared with regular toothpaste, charcoal-based toothpaste was found to be more abrasive and should be thoroughly researched before being prescribing to patients who have ceramic prostheses [13]. In contrast, the composite materials did not show any clinically perceivable (<3.3) change at all times when tested with whitening toothpaste [28].

Lower mean $\Delta E_{00}$ values were found by Derafshi et al [21] for feldspathic and zirconia ceramics after immersion in chlorhexidine and Listerine mouthwash and were within the clinically acceptable range. This could be explained by the immersion time (7 days) which was less than the staining time in the present study. Marginal $\Delta E_{00}$ values were registered by Haralur et al [25] for IPS e.max CAD samples after immersion in mouthwash (1.58±0.97), but values higher than are clinically acceptable were recorded for monolithic zirconia (4.86±2.21). Feldspathic ceramic material is more stainable than zirconia [21], and this is apparent in the results of the present study, since $\Delta E_{00}$ values for Vita Suprinity and Vitablocs Mark II feldspathic ceramic were 0.48 and 2.92, respectively. Miswak has been shown to reduce plaque and gingivitis, prevent caries, enhance gingival wound healing, have whitening capabilities, preserve orthodontic chain, and have oral cells biocompatibility in numerous investigations [9-11]. Nordin et al suggested that miswak helps maintain and manage dental health [43].

The compressive fracture resistance test measures the strength of ceramic dental prosthetic restorative materials in vitro. As it is suggested that the fracture resistance of restorations in the moist oral cavity is reduced by half, any restoration should withstand at least 1000 N of occlusal load, which is double the amount of the 500-N maximum bite force recorded [44,45]. Overall, the fracture resistance values recorded in the present study were near the clinically accepted values for the IPS e.max CAD group (829.21±101.79) but were much lower for the Vita Suprinity (340.63±55.93) and Vitablocs Mark II groups (312.65±19.33). Therefore, the second null hypothesis was partially accepted, because the IPS e.max CAD showed significant differences between the 3 types of miswak derivatives.
follows: 60% and 40% for the Vita Enamic, 30% and 70% for static load applications of chipping and bulk fracture, were as artificial ageing. The failure mode reported by Vafaee [51], after the different type of materials used, this could be related to the type of mechanical action the miswak derivatives applied on the surfaces of the tested ceramic materials in the present study as compared with that of the khat extract in the previous study, and neither study simulated the actual environment of the oral cavity. Khat shows changes on the surface of prosthetic materials [46,47], which can affect the strength of the ceramic and could be considered as a cause of varied fracture outcomes. IPS e.max CAD recorded the highest fracture strength in comparison with Vita Suprinity and Vitablocs Mark II, which was in accordance with the findings of Bankoğlu et al, Alakkad et al, and Sieper et al, who also recorded a higher fracture force among lithium disilicate samples, compared with zirconia or nano-ceramic samples [33,35,48]. Savaş et al assessed the fracture resistance of Empress CAD (1364.3±545.6 N), Lava Ultimate (1525±394 N), and CEREC (1231.9±412.2 N) ceramic materials following accelerated artificial ageing [49]. These force values were higher than the values recorded in the present study: 829.21±101.79 N for IPS e.max CAD, 340.63±55.93 N for Vita Suprinity, and 312.65±19.33 N for Vitablocs Mark II. These variances can be attributed to the various compositions of the CAD/CAM materials that were examined, even though the production technique was equivalent. According to the results of 1-way ANOVA (P=0.304), there was no significant difference between the groups in the study by Savaş et al [49], which was consistent with the findings of the present study.

In the present study, after 15 days of ageing, all samples were compressively loaded until they fractured using universal testing equipment. The failures in the 3 groups were of various types. Type 1, the reparable fractures, were associated mainly with IPS e.max CAD; however, this did not agree with the results of Alahmari et al [50], who recorded mainly catastrophic fracture among IPS e.max CAD groups. This could be because the recording was done for the compressive force for crowns cemented to natural teeth extraorally, while the present study assessed ceramic in the form of a rectangular block shape. Savaş et al [49], observed that 50% of tested specimens fabricated from zirconia and IPS Empress CAD revealed a reparable fracture type (within restoration) after accelerating artificial ageing. The failure mode reported by Vafaee [51], after static load applications of chipping and bulk fracture, were as follows: 60% and 40% for the Vita Enamic, 30% and 70% for IPS e.max, and 50% and 50% for Lava Ultima ceramic samples. In the present study, there were more type 2 and 3 fractures in the Vita Suprinity and Vitablocs Mark II samples than in the IPS e.max samples. This is similar to the findings of Al Moaleem et al, who examined zirconia and feldspathic ceramics [34]. For better understanding and analysis of failure type, longer times of storage and mechanical tests should be conducted. In the present study, similar values were found for Vita Suprinity and Vitablocs Mark II samples; therefore, we suggest confirming these results by measuring the surface topography and roughness of the specimens before and after application of the different oral hygiene aids.

The laboratory sample preparation, which did not replicate oral and clinical conditions, was one of the study’s potential limitations. Furthermore, artificial saliva was utilized to simulate an in vivo study in this work; therefore, more testing of in vitro and in vivo conditions is needed to evaluate more optical properties of CAD/CAM materials, such as gloss and surface roughness, with various forms of oral hygiene products.

Conclusions

Within the limitations of this in vitro study, the following conclusions could be drawn. With the exception of the miswak mouthwash group with IPS e.max CAD and Vita Suprinity, all mean ΔEa values were within the acceptable clinical range. IPS e.max CAD had better color stability than Vita Suprinity and Vitablocs Mark II. Higher mean ΔEa values were observed in the IPS e.max CAD and Vitablocs Mark II groups in association with miswak toothpaste use, whereas higher values in Vita Suprinity and Vitablocs Mark II were associated with the use of the miswak sticks. The color difference in the miswak mouthwash group for Vitablocs Mark II was significantly different from that of the IPS e.max CAD and Vita Suprinity groups. With miswak sticks, IPS e.max CAD had the highest mean compressive fracture resistance, whereas Vitablocs Mark II had the lowest compressive fracture resistance with miswak toothpaste and mouthwash. IPS e.max CAD was associated with type 1 fractures, whereas type 2 and 3 fractures were predominantly observed with the Vita Suprinity and Vitablocs Mark II groups.

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Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.
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