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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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Statistical Analysis C
Data Interpretation D
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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 (ΔE_{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 ΔE_{00} values. Moreover, miswak mouthwash had the lowest ΔE_{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 ΔE_{00} values were within the acceptable clinical range, with IPS e.max CAD showing superior color stability. The mouthwash group showed minimal ΔE_{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 adherence 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 Jassma 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_{00}) 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'Eclairage (CIELab) system [21,24,25]. Derafshi et al found mean ΔE_{00} 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_{00} 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_{00} values of 1.78, 2.241, and 1.58, respectively. Furthermore, monolithic zirconia ΔE_{00} 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_{00} 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.

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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 ΔE_{00} with values of alpha=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 Easyshade III, Vita Zahnfabrik H. Rauter GmbH, Bad Sackingen, 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 aides 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 ΔE_{00} values were calculated by the equation: $\Delta E_{00}=(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2)\times½$, where ΔL^* is the difference of L*, Δa^* is the variation of a*, and Δb^* is the variation of b* [20-22].

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Table 1. Fracture types and definitions.

Facture 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

Table 2. Mean ΔL*, Δa*, Δb*, and ΔE_{00} values after oral hygiene aids application for all-ceramic restorations.

Ceramic type	Oral aid type	ΔL*	Δa*	Δb*	ΔE_{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	-.010	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

ΔL* – mean L (lightness); Δa* – mean a (green-red); Δb – mean b (blue-yellow); ΔE_{00} – mean color change.

As noted in prior investigations, an ΔE_{00} value was connected with and equivalent to a perceptible threshold of ≥2.8 and a clinically acceptable threshold of ≥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 ΔE_{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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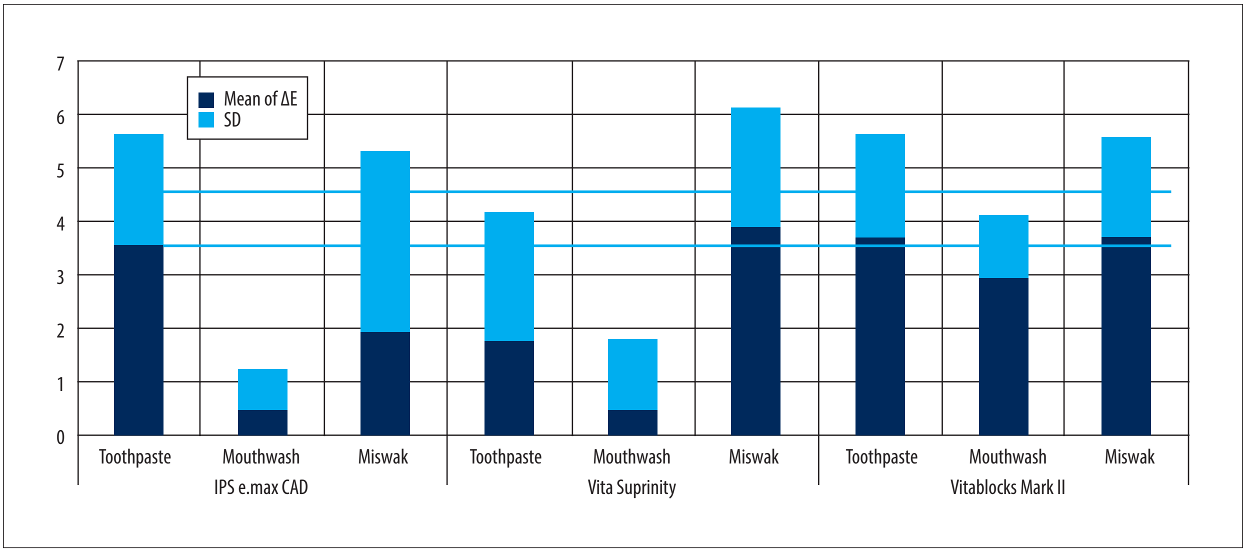

Figure 1. Mean and standard deviation of color change for different types of ceramic materials after application of miswak derivatives.

Table 3. Kruskal-Wallis analysis of ΔE_{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			
	Vitablocs Mark II	17.55			

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

Results

The mean ΔL*, Δa*, Δb* values and the ΔE_{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 ΔE_{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 ΔE_{00} values in Vita Suprinity and IPS e. max CAD samples, with almost the same value. Overall, the ΔE_{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 ΔE_{00} among the evaluated CAD/CAM all-ceramic restorative materials. The values of ΔE_{00} were significantly different in the mouthwash oral aid groups ($P \leq 0.001$). Vitablocs Mark II (25.35) had the highest mean rank, while Vita Suprinity ceramic materials had the lowest mean rank (8.30). The other groups for toothpaste and miswak sticks showed no significant differences with the 3 types of tested ceramic, with *P* values of 0.123 and 0.140 for the toothpaste and miswak sticks, respectively.

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

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Table 4. Mann-Whitney post hoc pairwise comparison between the ΔE_{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		No significance	
	Vita Suprinity			
	Vitablocs Mark II			
Miswak mouthwash	IPS e.max CAD	–	0.742	0.004*
	Vita Suprinity	0.742	-	0.001*
	Vitablocs Mark II	0.004*	0.001*	–
Miswak stick	IPS e.max CAD		No significance	
	Vita Suprinity			
	Vitablocs Mark II			

* The mean difference is significant at *P*≤0.05.

Table 5. Two-way repeated measures ANOVA results for values of ΔE_{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*≤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) Mean (SD)	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*≤0.05.

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 ≤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

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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			
	Miswak stick			
Vitablocs Mark II	Miswak toothpaste	No significance		
	Miswak mouthwash			
	Miswak stick			

* Significant difference at $P \leq 0.05$.

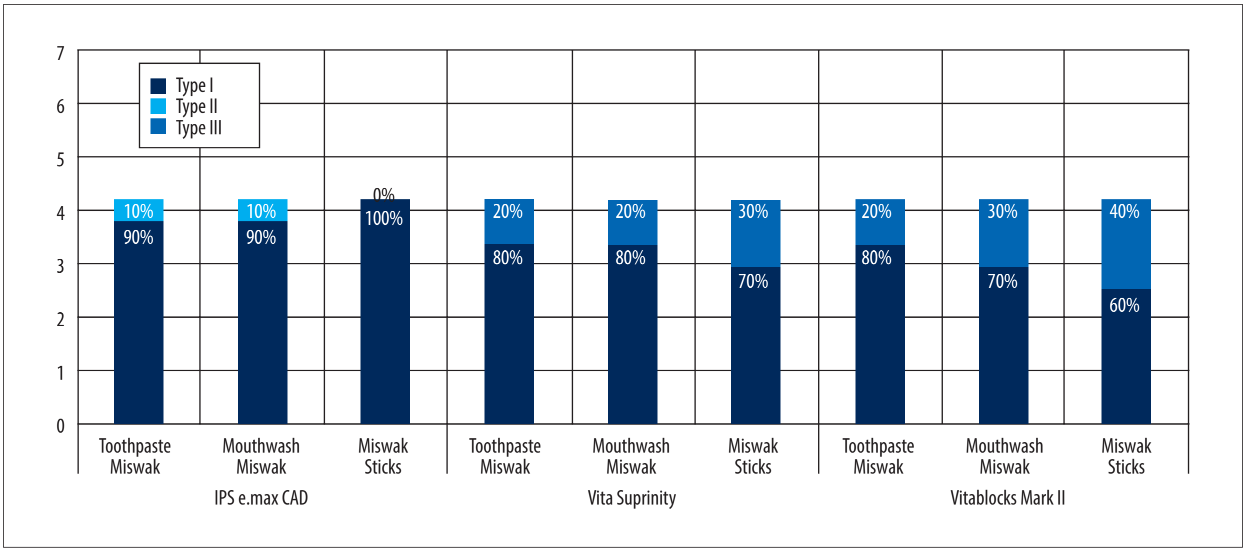

Figure 2. Percentage of failure types of tested CAD/CAM ceramic materials after compressive force application.

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 ΔE_{00} 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 ΔE_{00} were parallel with

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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 Easyshade 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 ΔE_{00} values should be between 2.8 and 4.2 units [22,23]. In the present study, the overall values of mean ΔE_{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 ΔE_{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 ΔE_{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 ΔE_{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 ΔE_{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 (Cerasmart 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 ΔE_{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 ΔE_{00} values were registered by Haralur et al [25] for IPS e.max CAD samples after immersion in mouthwash (1.588±0.97), but values higher than are clinically acceptable were recorded for monolithic zirconia (4.866±2.21). Felspathic ceramic material is more stainable than zirconia [21], and this is apparent in the results of the present study, since ΔE_{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 gingival inflammation, 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

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(*P*=0.051). Also, the 3 types of failures were recorded in the 3 types of ceramic and miswak derivatives.

Recently, Al Moaleem et al [34] reported a compressive force for feldspathic CAD/CAM materials (Vita Triluxe 396.25±42.24 N), which is higher than the value in the present study (Vitablocs Mark II 312.65±19.33 N); however, the zirconia groups in their study had higher compressive forces (777.42± 72.67 N and 533±50.71 N) than the Vita Suprinity (340.63±55.93 N) in the present study. Along with 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±19.33N 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 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 ΔE_{00} values were within the acceptable clinical range. IPS e.max CAD had better color stability than Vita Suprinity and Vitablocs Mark II. Higher mean ΔE_{00} 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.

References:

1. Vasiliu RD, Porojan SD, Birdeanu MI, et al. Effect of thermocycling, surface treatments and microstructure on the optical properties and roughness of CAD-CAM and heat-pressed glass ceramics. Materials. 2020;13:381
2. Leinfelder KF. Porcelain esthetics for the 21st century. J Am Dent Assoc. 2000;131(Suppl.):47S-51S
3. Joiner A. Tooth colour: A review of the literature. J Dent. 2004;32(Suppl.1):3-12
4. Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am. 2011;55(3):559-70
5. Skorulska A, Piszko P, Rybak Z, et al. Review on polymer, ceramic and composite materials for CAD/CAM indirect restorations in dentistry-application, mechanical characteristics and comparison. Materials (Basel). 2021;14(7):1592
6. Laborie M, Naveau A, Menard A. CAD-CAM resin-ceramic material wear: A systematic review. J Prosthet Dent. 2022 [Online ahead of print]
7. Jassoma E, Baeesa L, Sabbagh H. The antiplaque/anticariogenic efficacy of Salvadora persica (Miswak) mouthrinse in comparison to that of chlorhexidine: A systematic review and meta-analysis. BMC Oral Health. 2019;19:64
8. Dahiya P, Kamal R, Luthra RP, et al. Miswak: A periodontist's perspective. J Ayurveda Integr Med. 2012;3:184-87
9. Santhosh S, Jacob S, Thangakumaran S, et al. Miswak an indegenous plant in dentistry – A general outlook. Indian J Pharm Sci. 2018;2018:10-14
10. Shetti N, Metgud R, Pattar V, et al. Salvadora persica (Miswak) mouthwash: A promising home care agent. Ann Dent. 2016;4:6-9
11. Bhat PK, Kumar A, Sarkar S. Assessment of immediate antimicrobial effect of miswak extract and toothbrush oncariogenic bacteria – a clinical study. J Acad Adv Dent Res. 2012;3:25-29
12. Varma SR, Sherif H, Serafi A, et al. The antiplaque efficacy of two herbal-based toothpastes: A clinical intervention. J Int Soc Prev Comm Dent. 2018;8:21-27
13. Sulaiman TA, Camino RN, Cook R, et al. Time-lasting ceramic stains and glaze: A toothbrush simulation study. J Esthet Restor Dent. 2020;32:581-85
14. Haque MM, Alsareii S. A review of the therapeutic effects of using miswak (Salvadora persica) on oral health. Saudi Med J. 2015;36:530
15. Chen Y, Wong RW, McGrath C, et al. Natural compounds containing mouthrinses in the management of dental plaque and gingivitis: A systematic review. Clin Oral Investig. 2014;18:1-16
16. Kaur H, Jain S, Kaur A. Comparative evaluation of the antiplaque effectiveness of green tea catechin mouthwash with chlorhexidine gluconate. J Indian Soc Periodontol. 2014;18:178-82
17. Wulknitz P. Cleaning power and abrasivity of European toothpastes. Adv Dent Res. 1997;11:576-79
18. Joiner A. Review of the extrinsic stain removal and enamel/dentine abrasion by a calcium carbonate and perlite containing whitening toothpaste. Int Dent J. 2006;56:175-80
19. Joiner A. The cleaning of teeth. Handbook for cleaning/decontamination of surfaces. Amsterdam: Elsevier, 2007;234
20. Joiner A. A silica toothpaste containing blue covarine: A new technological breakthrough in whitening. Int Dent J. 2009;59:284-88
21. Derafshi R, Khorshidi H, Kalantari M, et al. Effect of mouthrinses on color stability of monolithic zirconia and feldspathic ceramic: an in vitro study. BMC Oral Health. 2017;17:129
22. Paul S, Peter A, Pietrobon N, et al. Visual and spectrophotometric shade analysis of human teeth. J Dent Res. 2002;81:578-82
23. International Organization for Standardization. ISO/TR 28642 Dentistry: Guidance on colour measurement. Geneva, Switzerland: ISO; 2016
24. Soygun K, Varol O, Ozer A, et al. Investigations on the effects of mouthrinses on the colour stability and surface roughness of different dental bioceramics. J Adv Prosthodont. 2017;9:200-7
25. Haralur SB, Raqe SAN, Alhassan Mujayri F. Effect of hydrothermal aging and beverages on color stability of lithium disilicate and zirconia based ceramics. Medicina (Kaunas). 2019;55(11):749
26. Alghazali N, Burnside G, Moallem M, et al. Assessment of perceptibility and acceptability of color difference of denture teeth. J Dent. 2012;40(Suppl.1):e10-17
27. Vichi A, Louca C, Corciolani G, et al. Color related to ceramic and zirconia restorations: A review. Dent Mater J. 2011;27:97-108
28. Hashemikamangar SS, Hoseinpour F, Kiomarsi N, et al. Effect of an optical whitening toothpaste on color stability of tooth-colored restorative materials. Euro J Dent. 2020;14:85-91
29. Gurgan S, Onen A, Koprulu H. In vitro effects of alcohol-containing and alcohol-free mouthrinses on microhardness of some restorative materials. J Oral Rehabil. 1997;24:244-46
30. Sasany R, Ergun-Kunt G, Yilmaz B. Effect of mouth rinses on optical properties of CAD-CAM materials used for laminate veneers and crowns. J Esthet Restor Dent. 2021;33:648-53
31. Lee JH, Kim SH, Yoon HI, et al. Colour stability and surface properties of high-translucency restorative materials for digital dentistry after simulated oral rinsing. Euro J Oral Sci. 2020;128:170-80
32. Stawarczyk B, Liebermann A, Eichberger M, et al. Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. J Mech Behav Biomed Mater. 2015;55:1-11
33. Bankoglu Gungor M, Karakoca Nemli S. Fracture resistance of CAD-CAM monolithic ceramic and veneered zirconia molar crowns after aging in a mastication simulator. J Prosthetic Dent. 2018;119:473-80
34. Al Moaleem MM, Alathwani AA, Alamir AA, et al. Effect of thermocycling and khat extract staining on the optical and mechanical properties of ceramic materials. Med Sci J. 2021;25:3146-56
35. Alakkad L, Kostagianni A, Finkelman M, et al. Biaxial flexural strength of various CAD-CAM glass-ceramic materials. Am J Dent. 2021;34:91-96
36. AlGhazali N, Burnside G, Smith RW, et al. Performance assessment of Vita Easy Shade spectrophotometer on colour measurement of aesthetic dental materials. Eur J Prosthodont Restor Dent. 2011;19:168-74
37. Perez Mdel M, Ghinea R, Herrera LJ, et al. Dental ceramics: A CIEDE2000 acceptability thresholds for lightness, chroma and hue differences. J Dent. 2011;39(Suppl. 3):e37-44
38. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent. 2007;97:200-8
39. Al-Dabbagh SA, Qasim HJ, Al-Derzi NA. Efficacy of Miswak toothpaste and mouthwash on cariogenic bacteria. Saudi Med J. 2016;37:1009-14
40. Pouranfar FL, Sheridan R, Salmon C, et al. Effect of toothbrushing on surface color of ceramic-polymer materials: An in vitro study. J Contemp Dent Pract. 2020;21:1054-58
41. Aydin N, Karaoglanoglu S, Oktay EA. Investigation the effects of whitening toothpastes on color change of resin-based CAD/CAM blocks. J Esthet Restor Dent. 2021;33:884-90
42. Yildirim B. Color stability and translucency of two CAD-CAM restorative materials subjected to mechanical polishing, staining, and prophylactic paste polishing procedures. EÜ Dişhek Fak Derg. 2021;42:1-8
43. Nordin A, Bin Saim A, Ramli R, et al. Miswak and oral health: An evidence-based review. Saudi J Biol Sci. 2020; 27:1801-10
44. Mehl C, Ludwig K, Steiner M, et al. Fracture strength of prefabricated all-ceramic posterior inlay-retained fixed dental prostheses. Dent Mater. 2010;26:67-75
45. Tinschert J, Natt G, Mautsch W, et al. Fracture resistance of lithium disilicate-, alumina-, and zirconia-based three-unit fixed partial dentures: A laboratory study. Int J Prosthodont. 2001;14:231-38
46. Al-Moaleem MM, Dafalla O, Alamir O, et al. Evaluation of color changes and surface topography of different feldspathic ceramic materials after Khat, Catha edulis extract immersion. Biosci Biotech ResComm J. 2020;13:160-68
47. Moaleem MMA, AlSanosy R, Ahmari NMA, et al. Effects of khat on surface roughness and color of feldspathic and zirconia porcelain materials under simulated oral cavity conditions. Medicina (Kaunas). 2020;56(5):234
48. Sieper K, Wille S, Kern M. Fracture strength of lithium disilicate crowns compared to polymer-infiltrated ceramic-network and zirconia reinforced lithium silicate crowns. J Mech Behav Biomed Mater. 2017;74:342-48
49. Savaş TY, Karaokutan I, Subaşi MG, et al. Evaluation of the fracture strength of different CAD/CAM inlay restorations after accelerated aging. Selcuk Dent J. 2019;6:155-62
50. Alahmari NM, Adawi HA, Moaleem MMA, et al. Effects of the cervical marginal relocation technique on the marginal adaptation of lithium disilicate CAD/CAM ceramic crowns on premolars. J Contemp Dent Pract. 2021;22:900-6
51. Vafaee F, Firooz F, Heidari B, et al. A comparative study of flexural strength and fatigue resistance of 2 nanoceramic composite resin CAD/CAM blocks (Lava Ultimate and Vita Enamic) and a lithium disilicate glass ceramic (IPS e. max CAD). Biomed Pharmacol J. 2017;10:51-58

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