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EXAMINING EFFECTIVENESS OF APP-BASED AUTOMATED TOOTHBRUSHING MONITORING TECHNOLOGY ON ORAL HYGIENE COMPLIANCE

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Abstract
Dental ceramics are commonly used for different clinical conditions as a restorative material. The increasing popularity of dental ceramics is attributed to their biocompatibility and their durability. However, during the past decade, some concerns have been raised regarding the changes in the color and surface roughness of different dental ceramics after the topical application of fluoride-containing products in toothpaste bleaching agents. This study aimed to examine the effects of different types of topical fluoride on glazed and non-glazed dental ceramics during the last decade through examining the medical literature. The literature was searched through Medline, PubMed, Embase, and Ovid databases in 2010 and 2020. The included searching terms were; fluoride, topical, and dental ceramics. A total of 542 articles were retrieved. Following the exclusion of review studies and including only original or experimental investigations, 17 articles appeared. Eight articles were identified as eligible, covering 574 dental ceramics treated with topical fluoride products. All the studies were *in vitro* studies. The study showed that topical fluoride application could lead to significant changes in color, gloss, and surface roughness of dental ceramics, predominantly glazed type. Further studies are required with a more robust design.

Keywords: Dental ceramics, fluoride, topical application, systematic review.

Introduction

The use of dental ceramics is increasing due to their high acceptability by patients of both genders and different age groups due to their excellent optical and esthetic properties [1]. However, due to the possibility of their fracture and wear, new advances have been developed to overcome their drawbacks by improving the internal structure [2]. Ceramics are varied in their crystalline structures, crystals shape and size, and the content of the glossy matrix. Based on their internal structure, it can be classified into polycrystalline, crystalline based with glass content, glass based with crystalline content, and glass-based ceramics [3].

The oral environment may harm dental ceramics. Multiple factors could affect dental ceramics and deteriorate their mechanical properties, such as the pH of the oral cavity, saliva composition, enamel thickness, the position of the dental ceramic, the contour, and the material for the antagonizing teeth, acidic food and drinks, patient's age and gender [4,5]. A recent study has investigated the wear mechanism of different ceramic materials using a ball-on-3-specimen tester, and it was reported that the zirconia had the lowest wearing rate [4].

Additionally, color stability and surface roughness could also be affected by multiple contributors. These include cigarette smoking and temperature changes inside the oral cavity, the brand and thickness of the ceramic, number of firings, condensation techniques, firing temperature, and dentin thickness [6]. Al-Thobity et al. [7] assessed the effect of three aqueous solutions on the flexural strength, elastic modulus, microhardness, and surface roughness of zirconia, lithium disilicate, and feldspathic porcelain. They found a significant effect on all tested physical properties of feldspathic porcelain, while zirconia and lithium disilicate ceramics significantly were affected in surface roughness and microhardness.

Immersing dental ceramics in different solutions such as water, or fluoride-containing products, can lead to some changes in the ceramic surface [8,9]. These changes include the destruction of the ceramic's surface due to the dissolution of oxide ions and increased roughness [10]. Although fluoride application is usually preferred as a preventive measure for dental caries, the topical application of fluoride can result in calcium salt formation [11]. This calcium precipitate is usually preserved from dissolution by salivary protein, yet the oral cavity's acidity can result in the release of fluoride [12].

Accordingly, fluoride ions are consistently released within the oral cavity, leading to dental ceramic degradation [6]. However, the effect of different fluoride- containing products on different types of dental ceramics is still conflicting [13,14]. Therefore, this systematic review was conducted to investigate the effects of topical fluoride application on the different types of dental ceramics.

Materials and Methods

This systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines (Figure 1) [15]. Articles presented in this review were original *in vitro* experiments that reported the effect of topical fluoride application on dental ceramics.

This systematic review was performed by searching electronic databases; PubMed/MEDLINE, Google Scholar, Ovid, and Embase to include eligible articles published from January 2010 to September 2020. Searching keywords included a combination of fluoride, topical, dental ceramics, dental porcelain, feldspathic porcelain, zirconia, lithium disilicate, color change, surface characteristics, and surface roughness.

Inclusion criteria of this review were: original *in vitro* studies, published in English language, assessed the impact of topical fluoride application on the dental ceramics and described clearly in the material and methods section the type of dental ceramics, type of topical fluoride, and in the results heading the effect of topical fluoride on the color and the surface characteristics of dental ceramics. The exclusion criteria comprised studies not published in English, review articles, case reports, and articles with incomplete data related to the testing protocol and the tested materials.

Based on the eligibility criteria, titles were reviewed extensively to exclude unqualified and duplicate articles, followed by an abstract review to confirm all the eligible articles. To ensure including all related articles, references of the selected articles and the relevant review articles were checked manually. A full-text review was carried out to identify articles that presented the required data and exclude those with unavailable full text, insufficient information, or inappropriate design. Finally, the required data sets were gathered from the final records of eligible articles and summarized. The required data were extracted from the included studies and tabulated in an Excel sheet (Microsoft Excel, Edition office 365, Microsoft Corporation, United States).

Results

After searching the different databases based on the eligibility criteria, eight articles were included in the present systematic review published between 2010 and 2020, covering a total of 574 discs treated topically *in vitro* with fluoride-containing products.

All eight studies [2,16-23] were experimental in-vitro studies that used different fluoride products and different types of dental ceramics. Acidulated phosphate fluoride (APF), a type of fluoride, was used in four studies [2,16,,20,22]. Also, sodium fluoride was investigated in four studies [17,18,20,23]. Only one study did not specify the type of fluoride used [21].

As for the type of dental ceramics, different types were examined. Lithium disilicate glass and Zirconia- reinforced lithium silicate ceramic were used in two studies [16,20], while three studies used feldspathic porcelain [17,18,21]. All the studies evaluated the effects of fluoride-containing products on the change in color and surface roughness of the included dental ceramic. The included studies are explained in detail in Table 1.

Two studies have shown a significant increase in the surface roughness of dental ceramics after fluoride application following dental bleaching [16,18]. While there was a significant change in the color of different types of glazed dental ceramics [2,18,22,23], and reduced microhardness was observed after fluoride application in two studies [18,20].

Discussion

Dental ceramics are commonly used for different clinical conditions as a restorative material [8]. The increasing popularity of dental ceramics is attributed to their biocompatibility and their durability [11]. However, during the past decade, some concerns have been raised regarding the changes that might occur on the color and surface roughness of different dental ceramics after the topical application of fluoride-containing products in toothpaste bleaching agents [2,16].

The present review investigated the effect of topical fluoride on glazed and non-glazed dental ceramics through reviewing the literature over the past decade. The review demonstrated that the most studied fluoride type was the acidulated phosphate fluoride [2,16,20,22]. It has been shown that there were significant changes in the color and surface roughness of different types of glazed dental ceramics [2,18,22,23]. In contrast, data on non-glazed ceramics requires further exploration.

Different types of dental ceramics were examined in this review. The effect of fluoride in the opalescence Pf on Feldspathic porcelain was examined by Ozdogan et al. [17]. It has been demonstrated that the fluoride in the used product was able to reduce the surface roughness of the ceramic significantly (p value < 0.05). At the same time, there was a non-significant difference in the color change of the ceramic (p value > 0.05).

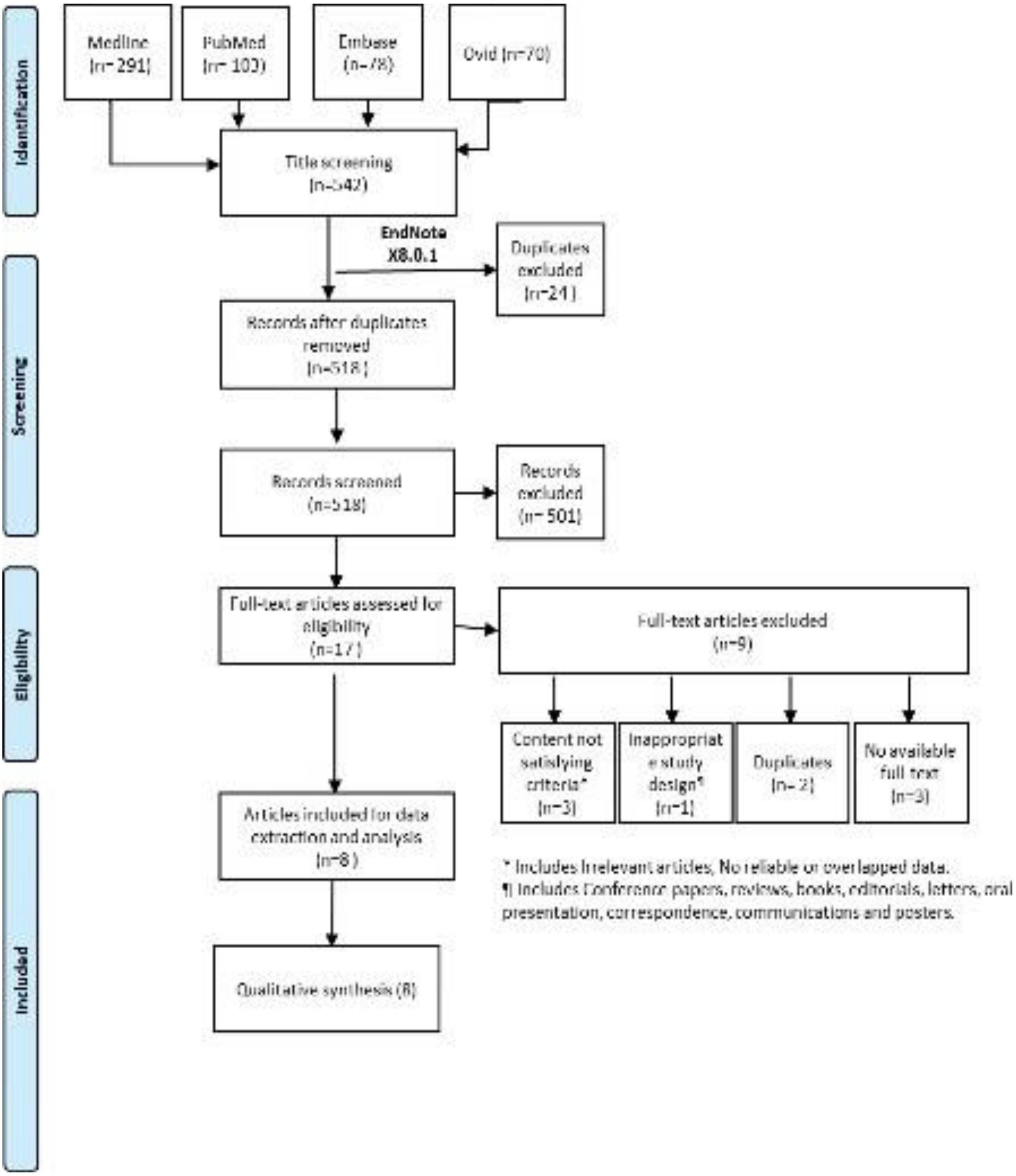

Figure 1. Flow chart of the included studies.

Similarly, Rodrigues et al. [18] examined different sodium fluoride concentrations on glazed feldspathic ceramic. Rodrigues et al. [18] showed that the microhardness and roughness were significantly reduced by fluoride (*p* value= 0.007 and 0.037, respectively). Also, there was a significant difference in the color and shade after application (*p*-value=0.041). These findings were also confirmed by Ural et al. [21], which showed a significant correlation between fluoride concentration in topical products and the effect on surface roughness of the ceramic restoration.
Moreover, in a recent study by Dawood et al. [16], it has been shown that acidulated phosphate fluoride can significantly affect the color of lithium disilicate glass and Zirconia-reinforced and lithium silicate ceramic. Furthermore, it has been shown that the type of dental ceramics [16].

Table 1. Included trials.

Author(s)	Year	Study design	Sample size (for fluoride application)	Type of fluoride	Fluoride concentration	Type of test	Type of dental ceramic	Result
Dawood et al. [16]	2020	*In vitro*	40	APF	1.23% sodium fluoride	color change and surface roughness	CAD/CAM dental ce- ramics (Lithium disilicate glass and Zirconia-re- inforced lithium silicate ceramic)	Fluoride application after bleaching of the ceramic materials showed higher color and surface roughness changes than bleaching application only
Ozdogan et al. [17]	2019	*In vitro*	20	Opalescence Boost and Opalescence Pf	1.1% sodium fluoride	Roughness and color change	Disc-shaped Noritake and Ceramco 3 felds- pathic porcelain	Both bleaching agents significantly affected the surface roughness while there was no significant effect on color stability.
Rodrigues et al. [18]	2019	In-vitro	44	Opalescence Tr` eswhite Supreme, Opalescence \ PF 15%	0.3% sodium fluoride, and 0.25% sodium fluoride, respectively	Surface roughness, micro-hard- ness, and shade stability	Glazed feldspathic porcelain	Fluoride-containing bleaching agents significantly affected the microhardness and shade stability. Additionally, the surface roughness was significantly lower in the brushed specimens after bleaching appli- cation.
Pires-de-Souza et al. [2]	2016	*In vitro*	60	fluoride; bleaching using 1.23% acidulated phosphate fluoride application	1.23% APF	Color stability and brightness	Glazed, polished, and glazed dental ceramics	Fluoride application only did not influ- ence the change of color or brightness. A decreased brightness occurred only in the group treated with bleach and fluoride.
Vechiato-Filho [20]	2015	*In vitro*	220	APF gel	0.05% NaF, or 0.2%NaF, or 1.23 APF	Micro- hardness, surface roughness	Lithium disilicate ceram- ics	Immersion in the test solutions diminished the microhardness and increased the sur- face roughness of the discs. The highest surface roughness results were observed in the 0.2% NaF and 1.23% APF groups.
Ural et al. [21]	2014	*In vitro*	40 (4 groups each of 10)	Topical fluoride	Each of the four groups was exposed to different concen- trations (10%, 15%, 20%, 35%)	Surface roughness	Feldspathic porcelain	A higher concentration of fluoride gel affected the surface roughness of test specimens significantly.
Can Say et al. [22]	2014	*In vitro*	40	Acidulated phosphate fluoride (APF)	1.23% sodium fluoride	Surface roughness	Glass-ceramicand leucite reinforced glass-ceramic, with glazed; or polished surface preparations.	APF showed insignificant surface roughen- ing for the polished ceramics, while glazed ceramics significantly affected by APF applications.
Artopoulou et al. [23]	2010	*In vitro*	80	SnF2 and NaF gels	0.4% SnF2 and 1.1% NaF gels	Surface roughness, surface gloss, color stability	Ceramic disks (IPS Em- press), 20 × 2 mm, Half of the disks were glazed, and the remaining disks were polished.	Fluoride treatment had a significant incre- ment in surface roughness and decrement in surface gloss after polishing or glazing ($p < 0.001$). In the case of 0.4% SnF2, ceramic disks showed a significantly higher surface roughness and lower surface gloss values ($p < 0.001$). Both fluoride prepara- tions caused a significant color change in the polished ceramic disks.

Additionally, the most extensive study, which included 220 disilicate lithium ceramics, by Vechiato-Filho et al. [20], examined the acidic solution's effect on dental ceramics after immersing them in different fluoride solutions. The study showed that fluoride application could make the surface of dental ceramics more susceptible to chelation with acidic solutions [20].
Also, the staining effects of SNF2 and NaF products were evaluated on glazed and polished ceramic disks by Artopoulou et al. [23]. It has been shown that the surface roughness was significantly higher in polished ceramics, while the surface gloss was significantly lower in both polished and glazed ceramics after treatment. Additionally, sodium fluoride should cause less deterioration and stain on the surface than SnF2 [23].
However, the included studies had some limitations. All the included studies were *in vitro* studies that might not simulate the *in vivo* environment, affected by the oral cavity's pH, saliva composition, acidic food and drinks, patient's age, and gender. However, this type of study can provide estimated effects of the ceramic and assess the influence of each of these contributors individually. Additionally, all the studies were limited by their sample size; hence, future studies should consider involving a larger sample size, representing the number of patients receiving dental ceramics. These limitations should be taken into consideration in future studies.

Conclusion
The application of fluoride-containing products on different types of dental ceramics can lead to significant changes in color, microhardness, and surface roughness. The changes have been shown to be more prominent with sodium fluoride, APF, and products with higher concentrations of fluoride compared to other fluoride products. Also, the most affected dental ceramics were the glazed ones. Further studies are needed to evaluate the long-term influence of fluoride-containing products on dental ceramics.

Conflict of interest
The authors declare that there is no conflict of interest regarding the publication of this article.

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