Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2022 Aug 07; 10(D):372-379.
https://doi.org/10.3889/oamjms.2022.10237
eISSN: 1857-9655
Category: *D - Dental Sciences*
Section: *Prosthodontics*

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Effect of Different Shading Techniques on the Color of Zirconia Ceramic Restoration (An *In vivo* Study)

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Edited by: Aleksandar Iliev
Citation: Elbadry M, Mohsen C, Hashem R. Effect of Different Shading Techniques on the Color of Zirconia Ceramic Restoration (An *In vivo* Study). Open-Access Maced J Med Sci. 2022 Aug 07; 10(D):372-379. https://doi.org/10.3889/oamjms.2022.10237
Keywords: Zirconia crowns; Shading techniques; CAD/CAM
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Received: 25-May-2022
Revised: 25-Jul-2022
Accepted: 28-Jul-2022

Funding: This research did not receive any financial support
Competing Interest: The authors have declared that no competing interest exists

Abstract

BACKGROUND: The color of all ceramic restorations has a significant effect on the final appearance of the restoration.

AIM: This study aimed to evaluate the effect of different shading techniques on the color stability of monolithic zirconia crowns cemented on the upper anterior teeth.

METHODS: In this study, there were nine patients. Each patient has undergone a reduction for the upper six anterior teeth. Fifty-four zirconia jacket crowns were constructed using CAD/CAM technique. According to the shading technique, the crowns were categorized into two groups (pre-shaded and liquid shaded), where the upper right reduced teeth received pre-shaded zirconia crowns while the upper left reduced teeth received liquid-shaded zirconia crowns according to the selected shade. The color was assessed using easy shade after cementation and 1 year follow-up period. Data were collected, tabulated, and statistically analyzed.

RESULTS: Color change (ΔE) of the cemented pre-shaded zirconia crowns on the upper right central incisors, lateral incisors, and canines was 2.37, 2.84, and 1.92, respectively, while color change (ΔE) of the cemented liquid-shaded zirconia crowns on the upper left central incisors, lateral incisors, and canines was 2.52, 2.88, and 2.77, respectively. Color change of both pre-shaded and liquid-shaded zirconia crowns after 1 year follow-up was within the clinically acceptable range 1>E>3.7, and there was no significant difference between them.

CONCLUSIONS: The aging and technique of shading had no significant effect on the color of zirconia ceramic.

Introduction

Extra coronal restorations are made from a variety of materials, including metal, metal ceramic, and ceramics [1]. The most important factors that may influence the final choice are strength and esthetics of the restoration. Although ceramometallic restorations have adequate characteristics, the opaque structure of the metal framework, chipping of veneering porcelain, and corrosion of non-precious metals lead clinicians for using all-ceramic restorations due to their natural looking appearance and pleasing esthetics [2].

All-ceramic restorations have lower mechanical properties so it has limited applications. To overcome this problem, reinforced dental porcelain has been developed like lithium disilicate, aluminum oxide, and zirconium oxide [3].

Among these new materials, zirconia has superior mechanical properties and it is the material of choice for cases with high loading force, in addition to its applications to various fields in dentistry due to the development of CAD/CAM technology [4].

Zirconia most useful mechanical properties are obtained in multiphase material known as partially stabilized zirconia [5]. Zirconia has a polymorphic structure that can exist in three crystal forms, a cubic structure stable at the highest temperatures, between the melting point (2680°C) and 2370°C, a tetragonal form stable at intermediate temperatures (2370–1170°C), and a monoclinic form stable at lower temperatures [6].

The volume expansion in t → m transformation may be controlled and exploited to give ceramics of high fracture toughness and strength with chemical and volume stability and suppresses crack progression by means of volume extension caused by the transformation toughening mechanism [5].

The high strength zirconia is generally overlaid with veneering porcelain which is prone to fracture. As a result, monolithic zirconia crowns are currently popular [7]. The optical characteristics of the restoration, including as light transmittance and reflectance, have a significant impact on its esthetics [3], and esthetic dentistry makes a concerted attempt to mimic the attractiveness of natural teeth [8]. Zirconia can be colored to achieve a good color match [3].

To overcome the cosmetic challenges, two procedures have been designed for coloring zirconia restorations: Either pigments are added to zirconia powder before pressing the milling blocks, or zirconia restorations are immersed in coloring liquids before sintering to achieve the appropriate shade. Manufacturers mix several oxides into the coloring fluid to achieve a variety of colors [9].

Color stability is as important as mechanical features for long-term clinical success because dental restorations are constantly exposed to multiple stresses in the oral environment that alter the physical and chemical structure of the restorations [10].

In vitro trials have been carried out to examine the influence of staining liquids on the color of zirconia ceramic [9] and to assess its color stability during aging [11]. Although these investigations reveal that the environment and elements that determine the color stability of the ceramic material may be precisely controlled, there is minimal association between *in vitro* findings and clinical performance [12].

A controlled clinical study is required due to the greater complexity of the clinical environment [13].

The purpose of this study was to see how coloring with staining liquid and aging affected the color stability of zirconia ceramic.

The null hypothesis was that shading technique had no effect on color stability in pre-shaded and liquid-shaded zirconia.

Materials and Methods

The research was a clinical trial with a 1-year follow-up period. The study was started in October 15, 2020, and ended in October 15, 2021. Nine patients were chosen to have their maxillary six anterior teeth restored with ceramic crowns. Before treatment, the patients were fully informed about the study's goals and design, and informed consent was acquired. The ethical committees of Minia University's Faculty of Dentistry reviewed and approved the study protocol at the meeting No. 71 for 2020 with approval No. 412.

Before beginning our work, the number of patients required in each group was determined after a power calculation according to data obtained pilot study. In that study the mean delta E in lateral, RT was 54.2 ± 2.8 and lateral, LT was 4.79 ± 2.43. A sample size of nine samples in each group was determined to provide 80% power for independent samples t-test at the level of 0.05 significance using G Power 3.1 9.2 software.

t-tests - Means: Difference between two independent means (two groups)

Analysis: A priori: Compute required sample size

Input: Tail(s) = Two

Effect size d = 1.4878535

α err prob = 0.05

Power (1-β err prob) = 0.8

Allocation ratio N2/N1 = 1

Output: Non-centrality parameter δ = 3.1562139

Critical t = 2.1199053

Df = 16

Sample size group 1 = 9

Sample size group 2 = 9

Total sample size = 18

Actual power = 0.8418641.

Inclusion criteria

1. Patients who need separate crowns for the upper six anterior teeth.
2. Patients with good oral hygiene.
3. Patients age between 30 and 40 years.
4. Male and female patients were included in the study.

Exclusion criteria

The following criteria were excluded from the study:

1. Patients with bad oral hygiene.
2. Anterior teeth with internal discoloration.
3. Patients refused to give an informed consent.
4. Smoker patients.
5. Endodontically treated teeth.

Fifty-four zirconia crowns were constructed. Crowns were divided into two groups according to the technique of shading (n = 27) where each group was further subdivided into three subgroups (n = 9) according to the tooth on which the crowns were cemented, as shown in Table 1.

Table 1: Grouping of the cases according to the technique of shading and the teeth on which the crowns were cemented

54 zirconia crowns (nine patients)					
Liquid-shaded zirconia crowns (27 crowns)			Pre-shaded zirconia crowns (27 crowns)		
Liquid-shaded zirconia crowns (27 crowns)			Pre-shaded zirconia crowns (27 crowns)		
(Upper left anterior teeth)			(Upper right anterior teeth)		
Canine (nine crowns)	Lateral incisor (nine crowns)	Central incisor (nine crowns)	Canine (nine crowns)	Lateral incisor (nine crowns)	Central incisor (nine crowns)

All teeth have undergone supragingival ultrasonic scaling using an ultrasonic scaler (Cavitron, Dentsply Intl, York, Pa) and were polished with plain white dentifrice (i-dental i-FASTE, Lithuania) using a rubber polishing cup (DENTP, China). Easy shade (VITA Zahn fabric, Bad Sackingen, Germany) was used to record preoperative shade for each tooth on each patient as a control shade.

A 0.9 mm subgingival heavy chamfer margin design was made using a tapered with round end diamond stone (Ceramic one, Lot 2013031125, USA) with an axial reduction of around 1.2 mm and incisal clearance of 1.8 mm, with the amount of reduction determined with the use of a depth gauge bur (Ceramic One, USA).

The preparations were finished with guided pin finishing burs (Ceramic One, Lot 2013031125) to obtain smooth surfaces. All tooth reduction principles were followed according to contemporary fixed prosthodontics.

The definitive conventional impressions were made after gingival displacement using a retraction cord (Retraflex, China) with the double cord technique.

For each case: First, the impression was scanned using Smart Optics extra oral Scanner (Smart Optics, Germany). Then, designing the restoration was done using exocad software, as shown in Figure 1.

Provisional crowns were constructed from PMMA material (EPAX 3D temporary, USA) by EPAX 3D Printer machine (EPAX 3D, Morrisville, USA) which were cemented on the corresponding teeth using eugenol free temporary cement (Rely X Temp NE; 3M ESPE).

Pre-shaded and un-shaded monolithic zirconia crowns were constructed by milling zirconia blanks (Zolid, Amann Girrbach, Germany) using imes-icore 5 axis milling system (CORTEC 250i, imes-icore, GmbH, Eiterfeld, Germany) after designing the restoration. The crowns were milled 25% larger than the required dimension to compensate for sintering shrinkage.

After milling, the crowns were polished using zirconia polishers (DIA SYNT Plus, Lot. 309705, DIACERA, Germany). Crowns were put for 20 min under the infrared drying lamp using Ceramill Therm 3 machine (Amann Girrbach, Austria).

The un-shaded zirconia crowns were colored by immersion in a suitable coloring liquid corresponding to the selected patient shade for each tooth following the manufacturer's instructions.

Sintering was done according to manufacturer's instructions at TABEO sintering machine (MIHM-VOGT GmbH, Stutensee Blankenloch, Germany) at 1550 c for 3 h. Sintered zirconia crowns were tried on the appropriate teeth for proper fit, contacts, and any occlusal adjustments before being submitted for glazing. In a Programat P310 ceramic furnace, the crowns' oral surfaces were vacuum glazed (Ivoclar Vivadent AG, Liechtenstein, Austria).

The fitting surfaces of both the pre-shaded and the liquid-shaded crowns undergone surface treatment by sandblasting using Renfert air blasting machine (Renfert GmbH-78247 Hilzingen, Germany) with 110 um AL_2O_3 particles.

Rely x™ U200 (3M ESPE, Neuss, Germany) self-etch self-adhesive resin cement was used to cement the zirconia crowns with the dentin surface of the teeth according to the manufacturer instructions where the cementation procedures were done by the same operator, as shown in Figure 2.

The color parameters (hue, value, and chroma) were recorded using easy shade (VITA Zahn fabric, Bad Sackingen, Germany) after cementation.

Where each crown underwent spectrophotometric analysis at a circular area of 1.5 mm on the middle of its labial surface with the probe tip positioned at 90 degrees to the surface of the tooth.

The patients were followed up for 1 year where they were invited to follow up visit by telephone calls. During the follow-up period, they were instructed to record the number and time of any uptake of colored foods and drinks, also to record the number and time of daily oral hygiene care.

Outcome assessment after 1 year follow-up

Survival rate

The survival rate was calculated using the percentage of single crowns that remained in situ with or without complications.

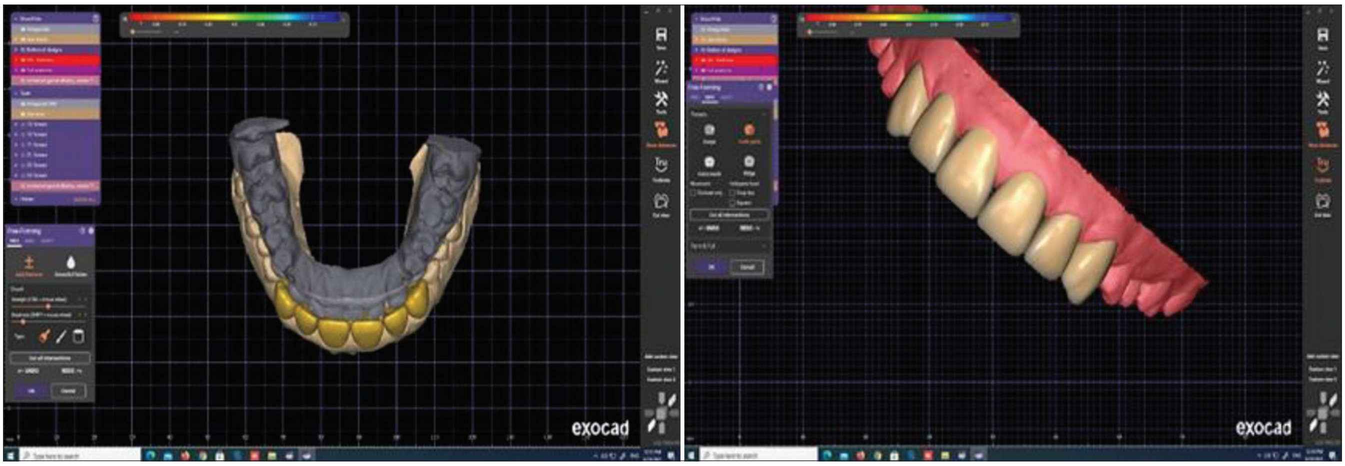

Figure 1: The final design of the restoration

Figure 2: Pre-operative photo for one of the cases and retracted plus smile photos for the same case after cementation

Complication rate

The cases were examined for any biological or mechanical complications.

Color measurement after 1 year follow-up period

The color parameters (hue, value, and chroma) were recorded after 1 year of follow-up following the same protocol which used after cementation and the change in color was recorded as ΔE from the equation:

$$\Delta E = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)\ ½$$

Where:

ΔL =L after cementation – L after 6 months follow-up.

Δb = b after cementation – b after 6 months follow-up.

Δa = a after cementation – a after 6 months follow-up.

a: measures the redness when plus and greenness when minus.

b: measures the yellowness when plus and blueness when minus

L: measures the lightness, it describes the achromatic character of color where 100 is white and 0 is black.

Experimental data were collected, tabulated, and statistically analyzed by Statistical Package for the Social Sciences version 25 Window software using Mann–Whitney U-test for non-parametric quantitative data between the two groups and Fisher`s exact test for qualitative data between the two groups significant level at $p < 0.05$.

Results

After 1 year follow-up, the results showed that:

Color change of the pre-shaded versus the liquid-shaded zirconia crowns cemented on the upper central incisors: In comparing the color change (ΔE) between the cemented pre-shaded zirconia crowns on the upper right central incisors of the patients which were included in the study (2.37) and the cemented liquid-shaded zirconia crowns on the upper left central incisors of the same patients (2.52), there was more color change with the liquid-shaded zirconia crowns. The color change between the two subgroups was statistically non-significant, p value (0.354), as shown in Figure 3.

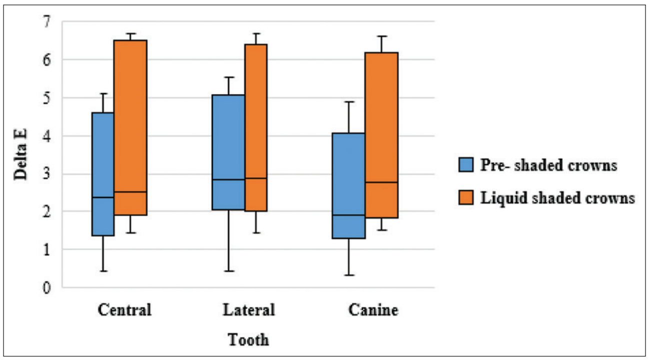

Figure 3: Color change (ΔE) of the cemented pre- shaded zirconia crowns on the upper right anterior teeth versus the cemented liquid-shaded zirconia crowns on the upper left anterior teeth

Color change of the pre-shaded versus the liquid-shaded zirconia crowns cemented on the upper lateral incisors: In comparing the color change (ΔE) between the cemented pre-shaded zirconia crowns on the upper right lateral incisors of the patients which were included in the study (2.84) and the cemented liquid-shaded zirconia crowns on the upper left lateral incisors of the same patients (2.88), there was more color change with the liquid-shaded zirconia crowns. The color change between the two subgroups was statistically non-significant, p value (0.627), as shown in Figure 3.

Color change of the pre-shaded versus the liquid-shaded zirconia crowns cemented on the upper canines: In comparing the color change (ΔE) between the cemented pre-shaded zirconia crowns on the upper right canines of the patients which were included in the study (1.92) and the cemented liquid-shaded zirconia crowns on the upper left canines of the same patients (2.77), there was more color change with the liquid-shaded zirconia crowns. The color change between the two subgroups was statistically non-significant, p value (0.270), as shown in Figure 3.

The number of patients who showed color change within the clinically acceptable range in the pre-shaded zirconia crowns which were cemented on the upper right central incisors was six patients which represents two-thirds of the patients (66.7%). While the number of patients which showed color change beyond the clinically acceptable range was three patients which represent one-third of the patients (33.3%), also the liquid-shaded crowns which were cemented on the upper left central incisors showed the same number and percentage. Furthermore, the same number and percentage were recorded with the crowns on the lateral incisors, as shown in Table 2.

Table 2: Number and percentage of cases that were within the clinical acceptable range or not regarding color change

Tooth	Delta E	Pre-shaded crowns n = 9	Liquid-shaded crowns n = 9	p-value
Central	Accepted	6 (66.7%)	6 (66.7%)	1
	Not accepted	3 (33.3%)	3 (33.3%)	
Lateral	Accepted	6 (66.7%)	6 (66.7%)	1
	Not accepted	3 (33.3%)	3 (33.3%)	
Canine	Accepted	7 (77.8%)	6 (66.7%)	0.599
	Not accepted	2 (22.2%)	3 (33.3%)	

The number of patients who showed color change within the clinically acceptable range in the pre-shaded zirconia crowns which were cemented on the upper right canines was seven patients which represents 77.8% while the number of patients which showed color change beyond the clinically acceptable range was two patients which represent 22.2% while the number of patients which showed color change within the clinically acceptable range in the liquid-shaded zirconia crowns which was cemented on the upper left canines was six patients which represent two-thirds of the patients (66.7%) and the number of patients which showed color change beyond the clinically acceptable range was three patients which represent one-third of the patients (33.3%), as shown in Table 2.

Discussion

The esthetic success of a restoration is dependent on the natural tooth form and color [14].

The anterior teeth were chosen for inclusion in the study because they represent the largest restorative challenge for physician [15].

Because variances in tooth color exist among people [16], among different teeth in the same person, and within the same tooth [17], shade selection for the crowns was done before teeth reduction. When color fluctuates within the same tooth, color matching becomes more difficult [18].

Because the cervical region of the tooth might appear reddish or yellowish depending on whether it is affected by gingival pink for redness or yellowish from root color [19], the best description of front teeth is in the middle third of the tooth [20].

To reduce confounding variables, this *in vivo* investigation applied stringent inclusion criteria [21].

Because tooth color is the most important optical quality, it is determined by both internal and external morphology, such as outline form, size, shape, surface anatomy, and light reflection pattern, the patients in the study had a similar range of color [22].

The natural appearance of tooth tissues (enamel, dentin, and pulp) is determined by their thickness, composition, calcification, and translucency, which are ultimately responsible for the crown's polychromatic qualities [23]. The thickness of enamel and dentin varies between teeth and also between various regions of the same crown [24].

The patients had a close pulp size, which was verified by periapical and panoramic X-rays taken for each patient, because the volume of the pulp chamber and the vitality of the tooth fluctuate at different stages of tooth development [25].

The patients were all in the same age range since there is a link between patient age and tooth color, with the teeth, particularly the central incisors, becoming darker with age, producing a more red and yellowish tone [26].

In this study, we used vital teeth to avoid the expected discoloration of endodontically treated teeth and teeth were in a close color range without any intrinsic discoloration because zirconia ceramic had partial translucency [27] which cannot hide the color of the underlying substrate [28].

This study used a horizontal margin design, which is widely utilized and regarded as the gold standard in academia [29].

Because monolithic zirconia with a heavy chamfer finish line has a higher fracture load, the preparations included a heavy chamfer finish line [30].

The sintering step plays an important role in the translucency of monolithic zirconia and has a direct effect on the amount of cubic phase, yttria distribution and grain size [31]. Various sintering temperatures had been used by many studied, 1300, 1350, 1400, 1500, 1550, 1600, and 1700°C [10].

Sintering zirconia using long cycles and high temperatures would result in better translucency [32], however, the highest fracture strength was observed for zirconia sintered between 1400°C and 1550°C, where above 1600°C, the flexural strength decreased significantly [10].

The crowns were tried inside the patient mouth prior to glazing for detecting accuracy of fitting, contacts, and any occlusal adjustment to avoid removal of the glazing layer by occlusal adjustment [33] that may lead to more abrasive wear of the opposing teeth. The margins of each crown were evaluated using dental explorer and a magnification loupe to assess the marginal fit of the restorations as the increased marginal discrepancy results in a thick layer of cement affected by the oral cavity environment, causing cement dissolution with further tooth biofilm accumulation and marginal discoloration [34].

The long-term effectiveness of all ceramic restorations depends on a strong and durable bond between the tooth structure, luting cements, and ceramics [35]. Sandblasting was used to treat the fitting surfaces of the crowns because it is thought to create surface roughness and irregularities, increase the surface wettability of the ceramic surface, and clean the substrate's surface, allowing the resin cement to flow into the surface [36].

Self-etch self-adhesive resin cement was used in the cementation process because it binds effectively to non-silica-based polycrystalline materials. Due to the semi-translucent optical properties of zirconia ceramic, light transmission through the zirconia ceramic structure can be predicted in zirconia-based restorations [37].

Because the underlying materials, such as cements, could affect the color, this study used a universal toned cement. Salinization is important because it decreases the surface tension of the substrate, wets it, and increases its surface energy, which allows for successful bonding [38]. A spectrophotometer was used to determine shade since it allows the dentist and technician to communicate important information to each other [39].

The present study discovered that liquid-shaded crowns cemented on the upper left anterior changed color more than pre-shaded crowns cemented on the upper right anterior after 1 year, however, the difference was not statistically significant. 1>E>3.7 was the difference, which is regarded clinically acceptable. Our findings matched those of (hang-yuan Zhang *et al*., 2021, who investigated the effect of aging on the color and translucency of monolithic zirconia and determined that color change after aging was within the clinically acceptable range [40].

A skilled person can detect the difference in color between pre-shaded and liquid-shaded crowns.

This is consistent with the findings of Ashy *et al*., 2021, who found that the color change value in zirconia ceramic is noticeable but clinically acceptable for all specimens [41].

The color of luted dental ceramics changes with age, depending on the aging conditions, and can be related to changes in the color of the ceramic and/or the underlying cement. Loss of surface stain, increased surface roughness, the occurrence of surface cracks, and a change in ceramic translucency can all cause discoloration in ceramic materials [42].

Despite the fact that the color change in all groups was within the clinically acceptable range in the present study, there were a number of patients in each group whose findings were outside of the clinically acceptable range. By reviewing the charts of such patients, we discovered that they were either heavy smokers and did not give oral hygiene any importance, or excessive uptake of coffee, tea, cola, and Nescafé.

These findings were in accordance with those of James *et al*., 2017, and Coelho *et al*., 2017, who found that oral hygiene is a key component in reducing dental caries and gingivitis, therefore, dentists prescribe chemical plaque control agents to patients undergoing fixed prosthodontic treatments [43], [44].

These findings were also consistent with those of Artopoulou *et al*., 2010, and Guignone *et al*., 2015, who found that plaque accumulation, stains from solutions, surface roughness, and chemical degradation all influenced the color of restorative materials, all of which could be caused by drinking tea or coffee [45], [46].

Conclusions

1. Coloring techniques and aging had no significant effect on the color stability.
2. Oral hygiene measures are important factors for maintaining long-term esthetic success of the restoration.

Recommendations

1. Both pre-shaded and liquid-shaded zirconia crowns can be used *in vivo* as they can maintain a color change within the clinically acceptable range after aging.
2. Patient selection is critical to the long-term success of the restoration.

Limitations of the study

1. Few number of patients during patients selection revealed that they are not smokers but later on and during follow-up period, we noticed that they are smokers, so there should be a way to overcome the lying of patients.
2. The follow-up period was short.
3. The difficulty of obtaining a standard method for *in vivo* application.

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