Effect of different polishing systems on the surface roughness of full-contour zirconia

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ABSTRACT

Background: Adjustment of any premature occlusal contact of any zirconia restoration requires its polishing or glazing in order to restore the smoothness of the restoration. The objective of this *in vitro* study was to evaluate the effects of different polishing systems and glazing on the surface roughness of full-contour zirconia.

Material and methods: Forty disks (diameter: 8 mm, thickness: 6.4 mm) were prepared from pre-sintered full-contoured zirconia block; they were colored and sintered in a high-temperature furnace at 1500°C for 8 hours. The specimens were then leveled and finished using grinding and polishing machine and adjusted using diamond disk. The specimens were then randomly divided into four groups (n=10), group I involves samples that were polished using (karat diamond polishing set, Vita zahnfabrik, Germany), group II involves samples that were polished with (zirconia polishing kit, SMEdent, Shanghai, China), group III involves samples that were polished with (OptraFine® diamond polishing system, Ivoclar Vivadent, Germany), while group IV involves samples that were glazed using glazing medium (VITA Akzent Glaze AKZ 25, Vita zahnfabrik, Germany). Surface roughness values (Ra) (in μm) of all the specimens were recorded at each stage of surface treatment of zirconia disks (leveling and finishing, adjustment of the samples and polishing / glazing) using surface roughness tester. Statistical analysis was carried out using one-way ANOVA and LSD tests.

Results: The results showed that the glazing group recorded the lowest surface roughness mean value, followed by (OptraFine® polishing system), then (zirconia polishing kit) and finally (karat polishing set) which showed the highest mean of surface roughness. For all groups, there was a statistically very high significant difference of (Ra) value before and after adjustment of the samples. Moreover, there was a statistically very high significant difference in (Ra) value when comparing the adjusted samples with the polished and glazed ones. Karat polishing set group showed a statistically highly significant difference with zirconia polishing kit group (P<0.01). Both, karat polishing set and zirconia polishing kit groups showed a statistically very highly significant difference (P<0.001) with (OptraFine® polishing system) and glazing groups. On the other hand, no statistically significant difference was found between glazing and (OptraFine® polishing system) groups (P>0.05).

Conclusions: Adjusting full-contour zirconia with diamond bur or disk resulted in a significant increase in (Ra) that necessitates its polishing or glazing to restore the surface smoothness. Furthermore, both glazing and OptraFine® polishing system provided the best surface smoothness, so glazing can be substituted with chairside polishing using OptraFine® polishing system.

Keywords: surface roughness, zirconia, glazing, polishing. (J Bagh Coll Dentistry 2014; 26(4):39-45).

الخلاصة

إن تعديل أي إطباق مبكر سواء لتركيبات السيراميك أو الزركون, يتطلب تلميعها أو إعادة تزجيجها من أجل استعادة النعومة المطلوبة. إن الهدف من هذه الدراسة المختبرية هو لتقييم آثار نظم التلميع المختلفة و التزجيج على خشونة سطح الزركون المعدل.

تم تحضير أربعين عينة من الزركون، تم تلوينها و طبخها في فرن ذو درجة حرارة عالية (1500 درجة مئوية لمدة 8 ساعات).بعد ذلك تم تسوية اسطح العينات و صقلها بواسطة جهاز الصقل, و بعدها تم تعديل أسطح العينات بواسطة قرص ماسي. تم تقسيم العينات بعدها عشوائيا إلى أربع مجموعات كل مجموعة تحوي عشرة عينات.المجموعة الاولى تم تلميع أسطح العينات فيها بواسطة (طقم التلميع الماسي Karat), في المجموعة الثانية تم تلميع أسطح العينات بواسطة (طقم التلميع الخاص بالزركون), المجموعة الثالثة تم تلميع أسطح عيناتها بواسطة (طقم التلميع الماسي Optrafine®), المجموعة الرابعة تم تزجيج العينات فيها بمادة تزجيج مناسبة. تم تسجيل قيم خشونة الأسطح (بالميكرو متر) لجميع العينات في المراحل الثلاثة (التسوية والصقل، تعديل سطح العينات ,تلميع العينات/ تزجيجها) باستخدام جهاز قياس خشونة السطح (البروفيلوميتر). وقد أجري التحليل الإحصائي بتطبيق اختبار ANOVA احادي الاتجاه و إختبار LSD.

أظهرت مجموعة التزجيج أقل متوسط خشونة لأسطح العينات، تليها مجموعة (طقم التلميع الماسي Optrafine®)، ثم مجموعة (طقم التلميع الخاص بالزركون), وأخيرا مجموعة (طقم التلميع الماسي Karat) والتي أظهرت أعلى متوسط خشونة. للمجموعات الأربع، كان هناك فروق ذات دلالة إحصائية عالية جدا بين متوسط الخشونة قبل تعديل العينات و متوسط الخشونة بعد تعديلها. أيضا كان هناك فروق ذات دلالة إحصائية عالية جدا في متوسط الخشونة بعد تعديل العينات و متوسط الخشونة بعد تلميع- تزجيج العينات. أظهرت مجموعة (طقم التلميع الماسي Karat) فرق معنوي عالي إحصائيا مع مجموعة (طقم التلميع الخاص بالزركون) (0.01> P). وأظهر كل من (طقم التلميع الماسي Karat) و (طقم التلميع الخاص بالزركون) فرق ذات دلالة إحصائية عالية جدا مع مجموعة (طقم التلميع الماسي Optrafine®) و (التزجيج) (0.001> P). بينما لم يظهر هناك اي فرق معنوي ذات دلالة إحصائية بين مجموعتي (طقم التلميع الماسي Optrafine®) و (التزجيج) (P=0.774).

و كإستنتاج، فان نتائج البحث اشارت الى أن تعديل سطح الزركون بواسطة قرص او مثقب ماسي أدى إلى زيادة كبيرة في متوسط الخشونة، مما يوجب ضرورة تلميع سطح الزركون أو تزجيجه لإستعادة نعومة السطح. قدم كل من (طقم التلميع الماسي Optrafine®) و (التزجيج) أفضل نعومة لسطح الزركون مع عدم وجود اي فرق احصائي بين المجموعتين. و بالتالي , من الممكن ان يكون تلميع سطح تركيب الزركون بواسطة (طقم التلميع الماسي Optrafine®) معوضا عن الحاجة لتزجيج تركيب الزركون مع الحصول على نعومة سطح مشابهة.

INTRODUCTION

Zirconia has been considered to have great potential as substitutes for traditional materials in many biomedical applications. Since the end of the 1990s, the form of partially stabilized zirconia has been promoted as suitable for dental use due to its enhanced biocompatibility, low radioactivity, interesting optical properties, excellent strength and superior fracture resistance as result of an inherent transformation toughening mechanism [1]. Dental use is trending toward full-contour zirconia, which is a solid zirconia restoration with no porcelain overlay that promises an end of fractured esthetic porcelain on crowns and bridges especially in posterior teeth [2].

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Although zirconia restorations have excellent properties that meet requirements of a prosthetic material, they have several drawbacks, one of them is: irreversible wear of opposing tooth structure. The most extreme wear damage occurs when a restoration with a rough surface contacts tooth enamel or underlying dentin [3].

A smooth restoration surface is important to avoid dental complications such as plaque formation, gingivitis, periodontitis, and wear of the opposing dentition. It is also important for patient comfort [4].

For many years, standard clinical and laboratory techniques indicated that any adjusted restoration (dental ceramic or zirconia) should be re-glazed to restore the surface smoothness; however, re-glazing is not always convenient or possible. The surface roughness of polished and glazed dental ceramic have been compared by many investigators[5-14], some of them found that the mechanical polishing have provided a better surface smoothness than glazing, while the others have found the opposite. However, it is necessary that any occlusal adjustment to the dental restoration (ceramic or zirconia) be followed with either mechanical polishing or re-glazing.

MATERIALS AND METHODS

Fabrication of the samples:

Pre-sintered full-contour zirconia block disk of (9.5x1.4 cm) was cut into small prisms using electrical cutting saw. Each prism was then glued into a fitting pin that was eventually placed into a milling machine to be milled to the desired size and shape (diameter: 10 mm, thickness: 8 mm).

Each specimen was colored using a specific type of colouring liquid that was applied using a metal free brush. The specimens were then placed under a heat radiating infrared lamp (for 45 minutes) according to the manufacturer instructions to dry the coloured zirconia specimens that prevent damage to the furnace heating elements by acid contained in the color liquids.

The specimens were then sintered in a high-temperature furnace at (1500°C for 8 hours including cooling) according to the manufacturer instructions. After sintering, the dimensions of each specimen were (diameter: 8 mm, thickness: 6.4 mm) due to the shrinkage during sintering (about 20% shrinkage).

Stone block construction

Each specimen was then embedded in a rectangular-shaped block of stone (1.5x2.3x1.3 cm) in such a way that about 2 mm of the zirconia specimen is being outside the stone block and the long axis of the zirconia specimen being parallel to the long axis of the stone block using a surveyor.

Finishing of the specimens surfaces

The surface of each zirconia specimen was then leveled and finished with grinding and polishing machine using rotating aluminum-oxide papers at 600 rpm. Each specimen was flattened and leveled using (220, 320, 400, 600-grit papers) respectively. Each paper was used for five specimens and discarded. The grinding process was done under water cooling and for 30 seconds for each paper. Finally, the specimens were polished using aluminum oxide coated disks (800 then 1000-grit) mounted on a straight handpiece (5000 rpm) under water coolant.

In order to have standardization, a surveyor was used: the stone block was attached to the movable table of the surveyor, while the straight handpiece was attached to the upper member of the surveyor in such a way that the long axis of the handpiece being parallel to the long axis of the zirconia sample, and the aluminum oxide disk being parallel to the surface of the specimen. The arm of the surveyor that holds the straight handpiece was moved down in such a way that the aluminum oxide disk was kept in contact with the surface of specimen for 30 seconds. Each sample was polished with (800- and 1000- grit disk) for 30 seconds respectively. The specimens were then thoroughly washed and dried for subsequent surface roughness assessment. The surface roughness (Ra) (in µm) for each specimen was then calculated using a surface roughness tester (profilometer).

Adjustment of the specimens' surfaces

The adjustments of the surfaces of the specimens were done using a diamond disk mounted on a straight handpiece. A surveyor was used with the same standardization that was applied during finishing of the samples. The diamond disk was kept in contact with the surface of each specimen for 10 seconds, The surface roughness (Ra) (in µm) for each specimen was then calculated using a surface roughness tester (profilometer).

Sample Grouping

The specimens were then randomly divided into four groups (n=10) according to the type of surface treatment that was applied, in group I, the specimens were polished with (Karat Diamond Polishing Set). In group II, the specimens were polished with Diamond polishing set for Zirconia (SMEdent Medical Instrument Co., Shanghai,

China). In group III, the specimens were polished with (OptraFine® Diamond Polishing System, Ivoclar Vivadent, Germany). While in group IV, the specimens were glazed using (Akzent Glaze AKZ 25) glazing material (Vita zahnfabrik, Germany).

Polishing and surface treatment of zirconia samples

Standardization of zirconia polishing and surface adjustment was controlled using straight and contra-angled handpiece mounted on a surveyor carrying the polishing burs and disks. In order to have standardization while using contra-angled handpiece, the stone block was attached to the movable table of the surveyor, while the contra-angled handpiece was attached to the upper member of the surveyor in such a way that the long axis of the handpiece being perpendicular to the long axis of the zirconia sample, and the polishing surface of burs or disks being parallel to the surface of the specimen. The arm of the surveyor that holds the contra-angled handpiece was moved down in such a way that the polishing bur or disk came in contact with the surface of specimen.

During polishing, the vertical arm of the surveyor was moved in estimated continuous circular movement (7 cycles for about 10 seconds) to polish each sample [15,16].

For group I, Karat Diamond Polishing Set was used to polish the specimens, using diamond felt wheels impregnated with diamond polishing paste mounted on a straight handpiece at a speed of 7,000 rpm (7 cycles for 10 seconds). In group II, Zirconia polishing kit was used to polish the specimens, using (ceramic diamond grinder, rubber diamond finisher and rubber diamond polisher) respectively, mounted on a contra-angle handpiece at a speed of 10,000 rpm for both grinder and polisher, and at 15,000 rpm for finisher.

Each bur came into contact with the sample for 10 seconds according to the manufacturer instructions, this type of polishing set was used without the need of any polishing paste (according to manufacturer instructions). In group III, OptraFine® Diamond Polishing System was used to polish the specimens, using (finisher [optrafine F], polisher (optrafine P), brush with diamond polishing paste) respectively, mounted on a contra-angle handpiece at a speed of 10,000 rpm with water spray cooling for both finisher and polisher, and at a speed of 7000 rpm for brush with diamond polishing paste for high gloss polishing. Each bur was used for 10 seconds according to the manufacturer's instructions.

Group IV specimens were glazed using a glazing medium, glazing powder was mixed with glazing fluid to a thick consistency and applied by brush as thinly as possible to the zirconia specimens. The specimens were then sintered in high temperature furnace for about 17 minutes at 930˚C according to the manufacturer instructions.

Surface roughness measurement

This test was performed using a surface roughness tester (Profilometer) device that was used to verify the surface topography of the samples of all groups. For each specimen, three readings were recorded (first reading in vertical line, second reading in horizontal line and the third reading radial line)[16]. The mean value for each sample was then calculated.

RESULTS

The descriptive statistics including the mean values and the standard deviation of surface roughness of the four groups (in µm) (after polishing) is shown in table (1) and figure (1).

Table 1: Descriptive statistics including mean values and standard deviations (after polishing)

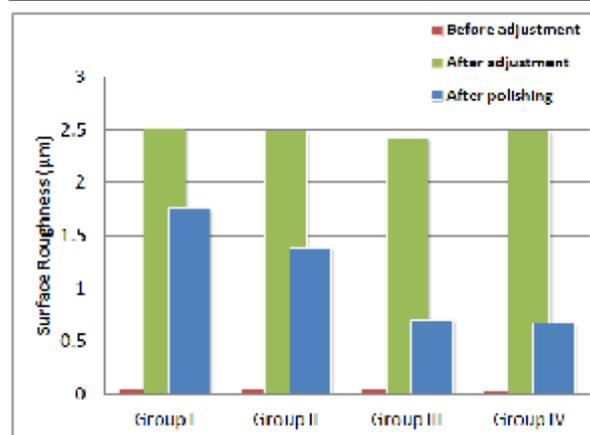| Groups	Mean	SD
Group I (Karat Polishing Set)	1.755	0.341
Group II (Zirconia Polishing kit)	1.379	0.296
Group III (OptraFine® Polishing System)	0.704	0.199
Group IV (Glazing)	0.670	0.203

Figure 1: Bar chart showing the mean values of surface roughness of the four groups (in µm) (before adjustment, after adjustment and after polishing).

The results showed that the glazing group recorded the lowest surface roughness mean value (0.670 µm), followed by OptraFine® diamond polishing system (0.704 µm), then zirconia

polishing kit (1.379 µm) and finally karat polishing set (1.755 µm) which showed the highest mean of surface roughness (Ra).For all the four groups, there was a very high statistically significant difference of (Ra) value before adjustment and after adjustment of samples. There was also a very high statistically significant difference in (Ra) value when comparing the adjusted samples with polished and glazed ones.

In order to see whether there is a statistically significant difference among the four groups after polishing; Analysis of variance (ANOVA) test was applied as shown in table (2).

Table 2: One-way analysis of variance (ANOVA) test among the four groups (after polishing)

ANOVA	Sum of Squares	Degree of freedom	Mean of Squares	F	Sig.
Between Groups	8.459	3	2.820	39.48	0.000 (VHS)
Within Groups	2.571	36	0.071		
Total	11.03	39			

(VHS): Very high statistically significant difference.

From Table (2), ANOVA test revealed a very highly statistically significant difference among the four groups (after polishing). In order to locate the difference between groups, further analysis of the data was performed using least significant difference test (LSD), as shown in table (3).

Table 3: Least significant difference test (LSD) between the different groups (after polishing)

Group I (Karat Polishing Set)	Group II (Zirconia Polishing kit)	Group III (OptraFine® Polishing System)	Group IV (Glazing)
•————————• (0.003)(HS)			
	•————————• (0.000)(VHS)		
		•————————————————————• (0.000)(VHS)	
	•————————• (0.000)(VHS)		
	•————————————————• (0.000)(VHS)		
		•————————• (0.774)(NS)	

(NS): statistically non significant difference.
(HS): statistically high significant difference.
(VHS):Very high statistically significant difference.

From table (3), Karat polishing set group showed a statistically high significant difference

with zirconia polishing kit group (0.01> P ≥ 0.001). Both, karat polishing set and zirconia polishing kit groups showed a very high statistically significant difference (P<0.001) with (OptraFine® polishing system) and glazing groups. Glazing and (OptraFine® polishing system) groups showed statistically non significant difference between them (P=0.774).

DISCUSSION

Zirconia restorations are generally considered an ideal solution for a variety of clinical applications, due to their durability, biocompatibility and natural esthetics. Dental use is trending toward full-contour zirconia, which is a solid zirconia restoration with no porcelain overlay. Ongoing material advancements have produced the strongest and most reliable all-ceramic restoration to date, making zirconia an ideal alternative solution wherever traditional metal or porcelain fused to metal (PFM) restorations might be prescribed [2].

Although zirconia restorations have excellent properties that meet requirements of a prosthetic material, they have several problems, one of them is: irreversible wear of opposing tooth structure under certain conditions, mainly due to high occlusal forces, which may occur because of parafunctional habits (i.e., clenching, bruxing), and premature occlusal contacts. The most extreme wear damage occurs when a restoration with a rough surface contacts tooth enamel or underlying dentin [3].

A smooth restoration surface is important in three terms: function, esthetics, and biologic compatibility, that avoids dental complications such as plaque formation, gingivitis, periodontitis, and wear of the opposing dentition. It is also important for patient comfort [4].

There are numerous instances in clinical practice when it is necessary to adjust a restorative surface by grinding. Such adjustments break the glazed or polished surface, resulting in a rougher surface and inferior surface properties of the restoration[17]. Early researchers agreed that re-glazing was necessary after restoration adjustment in the clinical setting [18]. Many dentists therefore, prefer the surface of a restoration to be re-glazed prior to cementation [19]. The introduction of intraoral polishing instruments or kits may be of great clinical importance, since they may substitute the laboratory re-glazing procedure [20, 21].

Bollen et al. [22] considered the critical surface roughness (Ra) means for bacterial colonization of several dental materials to be 0.2 µm. Surface roughness means higher than 0.2 µm are likely to

increase significantly bacterial adhesion, dental plaque maturation and acidity, which act on materials surface, thus increasing caries risk [23].

An increase in surface roughness can also be responsible for alterations in light reflection that can turn material surface opaque. It has been shown that a surface is considered reflective when imperfections are well below 1 μm [24].

Regarding the surface roughness measurement, the profilometer appeared to be the ideal device for studying surface roughness of restorative materials. This device gives quantitative measurements that can be calculated and compared statistically. Many researchers used this device to study the effect of polishing and glazing on the surface roughness of dental ceramics [6,9,11,25,26].

In this study, full contour zirconia samples were prepared and sintered; they were leveled and finished in order to flatten the samples surfaces so that the profilometer would be able to measure the surface roughness and to be ascertained that all the samples having approximately the same roughness values (before adjustment) that ensure the standardization of the work and to have a standardized base line data for all the samples. This was approved by the profilometric measurement of the samples.

The surfaces of the samples were then adjusted using diamond disk, due to the ability of diamond to adjust the extreme hard surface of zirconia restoration (crown or bridge); depending on Moh's hardness scale, the diamond has a score of 10 which is the highest among the abrasive materials, while Yttria-stabilized zirconia score ranges from 9 to 10 [27]. To simulate the clinical situation, every sample was adjusted with diamond disk for 10 seconds under water cooling.

Within the single group (roughness between different stages)

For all groups, there was a statistically very highly significant difference between (Ra) value before adjustment and (Ra) value after adjustment stage of samples, due to the roughening effect of the diamond disk on the samples surfaces.

In group I (karat polishing kit), statistically, there was a very high significant difference between (Ra) value after adjustment and (Ra) value after polishing of samples, meaning that there is a significant improvement in the surface smoothness of the samples compared to that after adjustment with diamond disk, a finding that concurs with the work of **Camacho et al.** [28] who concluded that robinson bristle brush, felt wheel and buff disk were efficient vehicles to be used in

association with a diamond polishing paste in polishing of feldspathic ceramic.

Statistical analysis of the data within each tested group, revealed statistically very highly significant difference in (Ra) roughness value between adjusted samples and after zirconia polishing and glazing, which proves the necessity of glazing and polishing of rough zirconia surfaces. This finding agrees with many previous studies [29-34, 14-16].

For all groups, despite the improvement in the surface smoothness, still the zirconia samples did not retain their original surface smoothness (after leveling and finishing), so that the polished and glazed samples were smoother than post-adjusted samples and at the same time rougher than pre-adjusted ones, and this was approved by very high statistically significant difference between (Ra) value before adjustment and (Ra) after polishing.

Effect of polishing systems

In group I, karat diamond polishing set was used to polish the zirconia samples; diamond felt wheels impregnated with diamond polishing paste were used. This group showed the highest mean value of surface roughness (Ra) in comparison to the other groups of polishing and glazing. Furthermore, there was a statistically very high significant difference with optrafine polishing set group and glazing group, and statistically high significant difference with zirconia polishing kit group. This means that the polishing with karat polishing set reduced the surface roughness produced the adjustment step but not to the level of smoothness as before adjustment. This could be attributed to lack of pre-polishing finishing of the zirconia samples (that was used in the other polishing groups) that would remove the minute scratches from the surface. This explanation agrees with **Freedman** [34] who stated "It is advisable to introduce intermediate finishing and pre-polishing devices (coated disks; rubber-like, bonded abrasives) between high-speed contouring-finishing burs and diamonds before applying polishing pastes for both composite and porcelain restorative materials".

In group II, zirconia polishing kit was used for polishing of the samples. This group showed the second highest mean value of surface roughness (Ra) measurement among the groups. This group showed a statistically very highly significant difference with optrafine polishing set group and glazing group, and a statistically highly significant difference with karat polishing set group. In this group, using the sequence of (grinder, rubber polisher, then a finer rubber polisher for final polishing) might contribute in

some way for getting a better result than karat polishing set group, despite lacking the use of diamond paste in this system.

In group III, OptraFine® diamond polishing system was used to polish the zirconia samples. This group showed lower (Ra) mean value than group I and group II (polishing groups), and slightly higher (Ra) mean value than glazing group. Statistically, group III has very highly significant differences with group I and group II, and in contrast, it had non significant difference with group IV (glazing). The smoothness of this group could be attributed to: first, the use of finishing and polishing burs in a sequential order that aided in eliminating the minute scratches found on the surface, second, the use of diamond paste in the final step. This explanation is totally in agreement with **Jefferies** [35] who stated "A three-body abrasive wear situation exists when loose particles move in the interface between the specimen surface and the polishing application device".

In group IV, the zirconia samples were glazed using a glazing medium that helped in obliterating any scratches that have been produced during surface adjustment. This group showed lower (Ra) mean value than karat polishing set group and zirconia polishing kit group, and slightly lower (Ra) mean value than OptraFine® polishing system group. Glazing group showed the smoothest surface, this group showed a statistically very high statistical significant difference with karat polishing set group and zirconia polishing kit group. This finding agrees with **Fuzzi et al.** [17] who concluded that profilometry and SEM (Scanning Electron Microscopy) for different surface treatments of ceramic showed that glazed surface was the smoothest one. There is also an agreement with the work of **Al-Wahadni** [5] and the work of **Al-Marzok and Al-Azzawi** [8] who found that the glazed ceramic was smoother than the polished one. There is agreement with **Yilmaz and Ozkan** [12] who concluded that the best method of restoring the surface smoothness is the glazing. There is an agreement with **Karayazgan et al.** [11] who reported that a polished surface of feldspathic porcelain was rougher than an overglazed surface. There is also an agreement with **Brentel et al.** [13] who found that the glazed feldspar ceramic has lower surface roughness than the polished one.

On the other hand, the glazing group revealed a non significant difference with OptraFine® polishing system group, a finding that is in agreement with the work of **Tholt et al.** [7], **Bottino et al.** [6], **Yuzugullu et al.** [10] and **Wang et al.** [9] who concluded that the mechanical polishing

produced similar superficial roughness to that of surface glazing. The disagreement came with **Sabrah** [14] who found a statistically significant difference between polishing full-contoured zirconia with (OptraFine® polishing system) and glazing them, where glazing scored lower (Ra) than polishing with (OptraFine® polishing system) in his study.

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