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WEAR OF HUMAN ENAMEL OPPOSING DIFFERENT TYPES OF DIRECT RESTORATIVE RESIN COMPOSITE MATERIALS

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ABSTRACT

Aim: to evaluate the wear of human enamel and different types of composite resin restorative materials when they oppose each other

Materials and methods: six different types of restorative resin composites (Grandioso, Activa, Z250, Brilliant everglow, CAPO, Herculite XRV) were opposed by human enamel in a chewing simulator (Robota, Germany) the chewing simulator was adjusted to perform a sliding distance of 1mm under a constant force of 50N while composite is in contact with enamel. the loss of weight of enamel and opposing composite was considered as a value for the wear.

Results: The highest wear was that of Grandioso heavy flow(5.8mg) followed by brilliant everglow (4mg) and Herculite ultra enamel(2.5mg) respectively and there was statistically significant differences among them as well as other materials. and the least values were recorded for CAPO (1.22mg), Z250 (1.24) and Activa (1.27) that were not statistically significantly different. Regarding opposing enamel wear the highest wear value was that of enamel opposing Brilliant everglow(7mg) and Z250 (6.4mg) both values were not statistically different. The values of Heculite ultra enamel (4.6) and Grandioso heavy flow (4mg) had no significant differences between them but showed significant difference with the above groups. The enamel wear opposing Activa (1mg) and CAPO (1.8mg) showed no statistically significant differences between them while they were significantly less than other groups.

Conclusions: Different composite formulations recommended for use in stress bearing areas have different wear rates, opposing enamel wear is important to study as it is independent of composite wear.

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INTRODUCTION

Wear of restorative composites is a major concern only in occlusal stress bearing areas and especially for patients with parafunctional habits as bruxism.(1-3) Randomized clinical trials revealed that there is no significant differences in wear between nonofilled composites and microhybrid composites.(4-7) Wear quantity and morphology is influenced by type of composite resins, normal force applied and presence of a third-body medium.(8–14) Two body wear studies revealed that, microfilled composite resin showed lower material loss with smoothly worn surface, whereas micro-hybrid showed greater material loss with cracks in the worn surface.(9,10) Microfilled composite wear in three body model in the presence of abrading slurry showed worn surfaces with greater failure.(11-16) Clinical evaluation of composite resin wear gives the most reliable information, despite that, laboratory wear data are still of value as numerous articles are continuously found in dental literature, reporting in vitro wear data produced with different wear testing devices.(3,19,20) However to assure reliable laboratory wear data, combination of at least two different wear settings is recommended to assess the wear resistance of materials.(21)

With the increasing number of nanofiller containing composite resins introduced to the market, it is still important to analyze the mechanisms resulting from two-body wear at direct contact between opposing tooth surfaces (occlusal contact area = OCA: attrition), and from three-body wear (contact free area = CFA: abrasion), occurring when a food bolus is compressed between antagonist teeth and abrading particles of food slide over the restoration surface.(22-25) Since in most cases occlusal restorations are affected by both mechanisms, it is reasonable that wear simulating devices should be designed to simulate both loading types. At this time, generally accepted in vitro wear testing methods are not approved. The ISO technical specification 14569-2:2001 "Wear by two- and/or three-body contact" gives broad recommendations.(26) Studies quantifying wear should preferably include morphological analyses of the wear patterns in order to explore the basic wear mechanisms under the different wear conditions. Apart from the production of wear patterns on specimens simulating in vivo conditions, it is equally important to apply quantitative evaluation methods, rather than semi-quantitative or qualitative methods.(27-29)

Composite resin restorative materials have undergone many developments to improve the outcome of the restorative procedures specially in posterior regions of the mouth. These improvements include nanofillers technology either true nanofills or nanohybrid fillers to achieve higher filler loading with improved mechanical properties and improved surface finish.(1) Bulk filling to save time without deleterious effects of polymerization shrinkage.(30)

Another modification is the layering technique where dentin and enamel shades are used to achieve maximum esthetics.(31) Bioactive materials releasing fluoride, Calcium and phosphate ions are also available for application in stress bearing areas aiming at improving tooth tissue remineralization.(32) Data on wear behavior of these newly introduced materials and antagonistic enamel wear is scarce. Hence this study was carried out to investigate the wear of some newly introduced composite resin materials intended for application in the posterior region of the mouth and to study the antagonistic enamel wear. The null hypothesis tested is no difference in wear between restorative materials and no difference in antagonistic enamel wear.

MATERIALS AND METHODS

The materials used in this study, their manufacturers, description and lot numbers are listed in table 1

TABLE (1) Materials, Manufacturers, Description and lot numbers.

Material	Manufacturer	Description	Lot No.
Grandioso heavy flow	VOCO, Cuxhaven, Germany	Flowable Universal nanohybrid restorative with filler loading 80% by weight.	1505123
Activa bioactive restorative.	Pulpdent corporation,MA, USA.	is an esthetic, bioactive composite that delivers the advantages of glass ionomers in a strong, resilient, resin matrix. It chemically bonds to teeth, releases fluoride and is more bioactive than glass ionomers, and is more durable and fracture resistant than composites.	150119
Filtek Z250	3M ESPE dental products, St. Paul, USA.	Microhybrid composite specifically designed for use in both anterior and posterior direct or indirect restorations.	
Brilliant everglow	Coltène, Whaledent AG Feldwiesenstr. 20 9450 Altstätten , Switzerland	Submicron hybrid universal composite.	G27644
CAPO universal	SCHUTZ dental group, Rospach, Germany.	Ultra-fine micro hybrid composite with improved abrasion characteristics.	2013001359
Herculite XRV ultra enamel	Kerr dental, Scafati, Italy.	Microhybrid composite enamel shade.	5181515

Composite resin material specimens preparation

Ten cylindrical specimens 4mm diameter x 6mm length were prepared from each material. The resin composite was packed in a split Teflon mold that was covered by celluloid matrix strip on its top and bottom. A glass slide was used to extrude excess material, followed by curing the composite specimens from top and bottom for 20s each using the light curing unit (Elipar S10 free light, 3M, ESPE, USA) with an output intensity of 1200 mW/cm^2. The light was checked for intensity every 10 specimens and in case there is drop of intensity the curing unit was put on the charger. After curing, the specimens were finished using ascending grits of silicon carbide paper 400, 600,800, 1000, 1200, to remove excess flashes and standardize the surface. the specimens were then kept in distilled water at 37^{o}C $\pm$1for 24hrs before wear test.

Enamel specimens preparation

30 human premolars extracted for orthodontic treatment were selected in this study. The teeth were caries and cracks free, the teeth were washed, disinfected using 1% thymol solution for 24 hrs after that teeth were stored in distilled water until used. The teeth were decapitated 1mm below the cemento-enamel junction, the crowns were sectioned buccolingually in their center to create two equal mesial and distal halves using a diamond disc in low speed hand piece under water coolant. This yielded 60 proximal enamel surfaces that were flattened through finishing with ascending grit silicon carbide paper. The enamel specimens were kept in distilled water until used.

Thermo-mechanical aging test was conducted using the four stations multi-modal ***ROBOTA*** chewing simulator* integrated with thermo-cyclic protocol (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) operated as wear simulator accompanied with thermo-cyclic mode, fig (1).

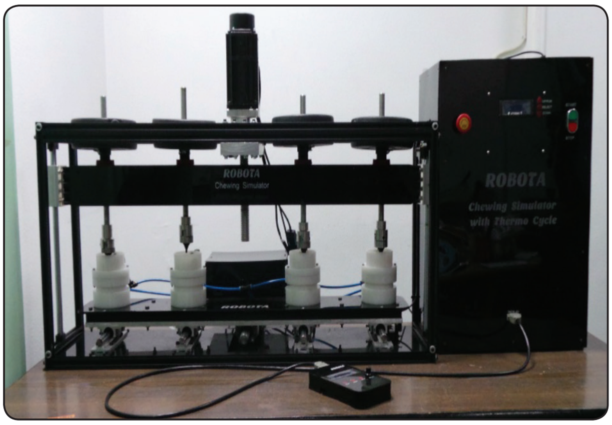


Fig. (1) Four chamber chewing simulator used for the wear test.

ROBOTA chewing simulator which has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each of the chambers consists of an upper stylus holder where composite specimens were tightened with a screw for use as antagonistic materials and a lower Teflon sample holder in which the enamel specimens were embedded (Fig. 2). A weight of 50 N of chewing force was exerted. The test was repeated 20000 times to clinically simulate the 6 month chewing condition, accompanying thermocycling.

TABLE (2) Test parameters for the chewing simulator during wear Process.

Test parameters	
Cold/hot bath temperature: 5°C/55°C	Dwell time: 60 s
Vertical movement: 2 mm	Horizontal movement: 1mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 3 Hz	Weight per sample: from 3 up to 10 kg
Torque; 2.4 N.m	

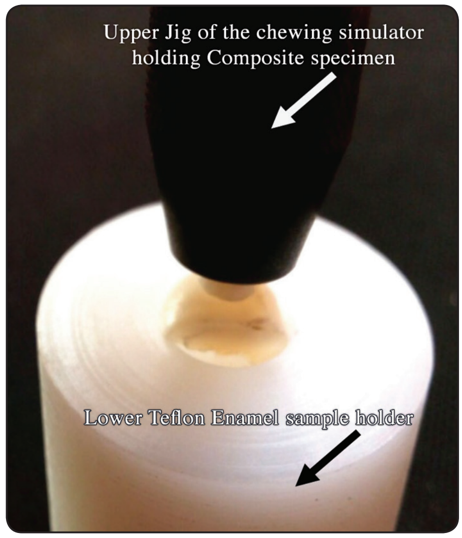


Fig (2) Test set up showing articulation of composite and enamel specimens in the wear simulator

SEM Evaluation

Two enamel specimens from each group were selected for SEM evaluation, the worn surfaces were sputter coated with gold using (S150A Sputter coater, UK). After sputter coating the specimens were examined under SEM (Quanta 250, FEI, Amsterdam, Holland) at a magnification of 100, 1000 and 1500 to evaluate the wear scars in enamel.

Statistical analysis

The data was collected tabulated and expressed as mean $\pm$ standard deviation. The data were subjected to test of normality using Shapiro-wilk test,g then One way ANOVA followed by Tukey's post hoc test for means comparison. The Pearson's coefficient of correlation was calculated for wear of composite and antagonistic enamel. The statistical analysis was performed using IBM, SPSS version 20.

RESULTS

The results of this study are shown in table (3) and figures(3 and 4)

The highest wear was that of Grandioso heavy flow(5.8mg) followed by brilliant everglow (4mg) and Herculite ultra enamel(2.5mg) respectively and there was statistically significant differences among them as well as other materials, and the least values were recorded for CAPO (1.22mg), Z250 (1.24)and Activa (1.27) that were not statistically significantly different. Regarding opposing enamel wear the highest wear value was that of enamel opposing Brilliant everglow(7mg) and Z250 (6.4mg) both values were not statistically different. The values of Heculite ultra enamel (4.6) and Grandioso heavy flow (4mg) had no significant differences between them but showed significant difference with the above groups. The enamel wear opposing Activa (1mg) and CAPO (1.8mg) showed no statistically significant differences between them while they were significantly less than other groups.

TABLE (3) Wear results in mg for both composite materials and opposing enamel.

		Mean wear in mg	SD
Restorative Materials	Herculite	2.5^{C}	0.6
	CAPO	1.2^{D}	0.2
	Z250	1.2^{D}	0.4
	Grandioso	5.8^{A}	1.3
	Bioactive	1.3^{D}	0.4
	Brilliant	4^{B}	0.9
Enamel Opposing Different Materials	Herculite	4.6^{c}	1.2
	CAPO	1.8^{b}	0.5
	Z250	6.4^{a}	1.2
	Grandioso	4^{b}	0.7
	Bioactive	1^{c}	0.2
	Brilliant	7^{a}	1

Different capital superscript letters indicate significant differences between composite materials wear, whereas small superscript letters indicate significant differences for antagonistic enamel wear.

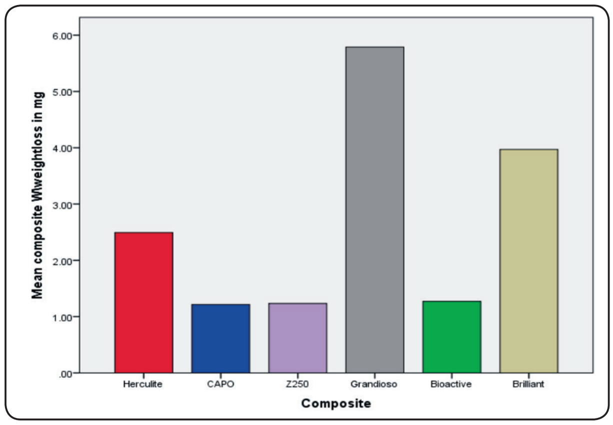


Fig (3) Bar chart showing values of composite wear against enamel in mg after 20,000 chewing cycles.

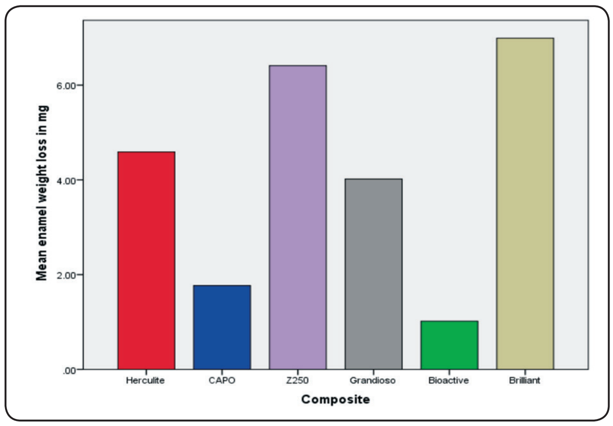


Fig (4) Bar chart showing values of human enamel wear against different materials in mg after 20,000 chewing cycles.

The correlation study showed very weak positive correlation between enamel wear and composite wear as indicated by a Pearson coefficient of only 0.28 as shown in table (4) .

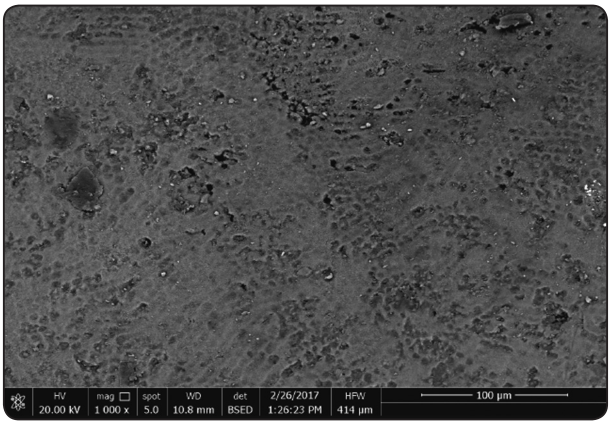
TABLE (4) Correlations between enamel wear and composite wear.

		Composite weight loss	Enamel weight loss
Weight loss	Pearson Correlation	1	.280*
	Sig. (2-tailed)		.030
	N	60	60
Enamel	Pearson Correlation	.280*	1
	Sig. (2-tailed)	.030	
	N	60	60

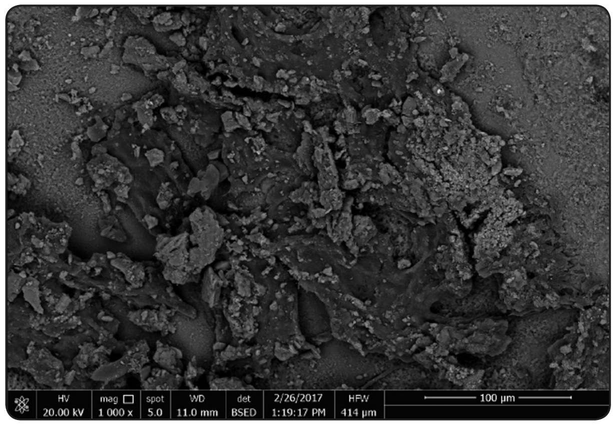
***. Correlation is significant at the 0.05 level (2-tailed).**

SEM Results

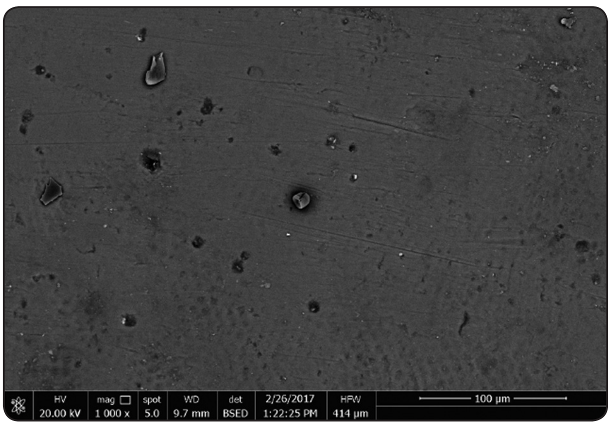
The SEM examination fig (5) revealed different patterns of enamel wear, these patterns of wear by fatigue and brittle fracture indicated by delamination and cracking of enamel within the wear scars. The different types of composites showed different degrees of aggressiveness of wear scars.



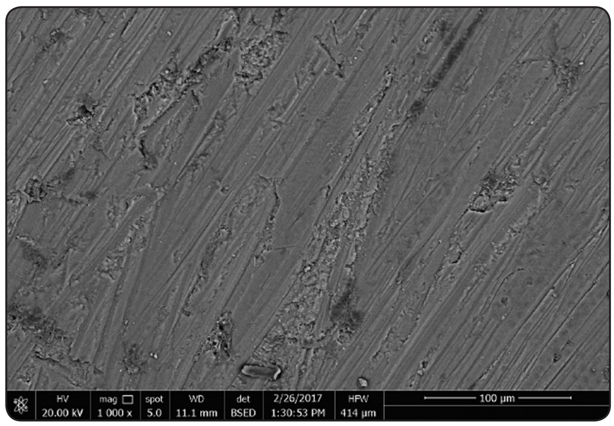
Wear scars of enamel opposing CAPO showing mild wear cracks and scaring.



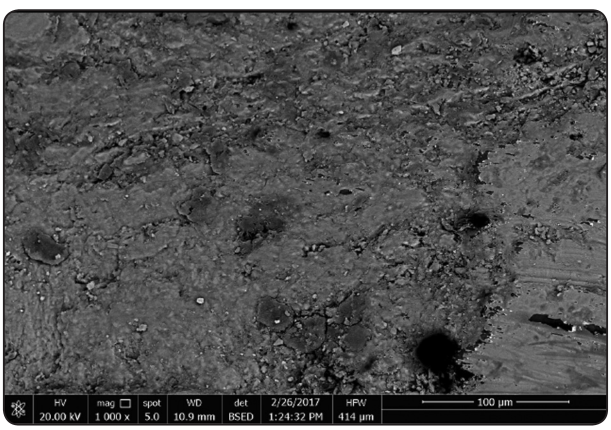
Wear scars of enamel opposing Grandioso heavy flow showing delamination of both enamel and restorative resin.



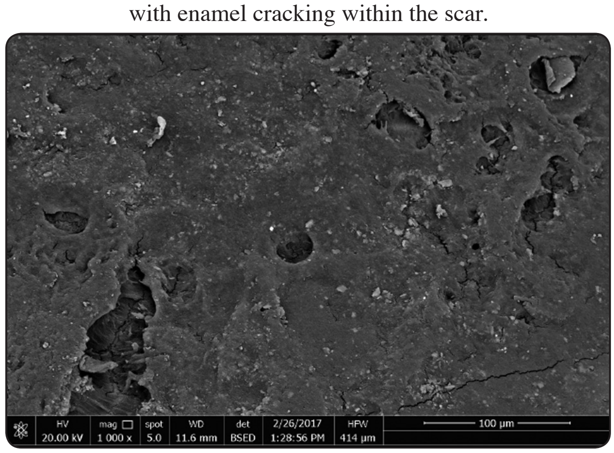
Wear scars of enamel opposing Bioactiva showing minimal scars.



Wear scars opposing Herculite ultra showing deep scratches with enamel cracking within the scar.



Enamel wear scars opposing Brilliant everglow showing massive enamel cracking and delamination.



Wear scars of enamel opposing Z250 showing delamination of enamel areas with little cracks.

Fig (5) SEM photomicrographs of enamel Against different Composite resin restorative materials

DISCUSSION

In this study six different commercially available direct composite resin restorative materials that are indicated for use opposing enamel in high stress occlusal situations were used. They were representing different categories of resin composite materials; heavily filled nanohybrid flowable composite, bioactive composite, microhybrid composite, submicron hybrid composoite, and ultrafine microhybrid composite. These materials were introduced with claims of manufacturers that they are antagonist friendly yet have high abrasion resistance. Hence this study evaluated the wear behavior of these materials and in the same time evaluated antagonistic enamel wear.

In the current study wear was evaluated using a design similar to a pin-on-disk wear-test rig, which has been very popular to simulate two-body wear between the sample and the antagonist.[17,33] This method uses a simple relative movement between the wear pair and gives relatively quick results. [33]

When direct contact occurs in the absence of third medium, two-body abrasion takes place when the surfaces are rubbed away.[20] In this study two body wear test setup was used as two body wear indicates the direct effect of the tested surfaces over one another with elimination of the effect of intermediate material like food. In the mouth, these conditions occur predominantly during non-masticatory tooth movement and are particularly prevalent in 'bruxism'.[20] Attrition is a form of two-body abrasion wear, which is the result of physiological or pathological proximal and occlusal inter-dental friction. Despite extensive knowledge of the histology and mechanical properties of enamel, little is known about the wear behavior of human enamel. Reviewing the existing literature, it is found that limited detailed research has been conducted to evaluate the friction and wear behavior of human enamel.[33]

The antagonist material opposing a natural tooth affects the wear behaviour of enamel and thus, an appropriate restorative material should be carefully selected to minimize the wear of natural dentition.[34] The results of this study showed that the least enamel wear was that opposing Bioactiva which is a bioactive ion releasing resin modified glass ionomer, this could be due to its relatively lower surface hardness compared to other materials. The highest enamel were was recorded opposing Brilliant everglow followed by Z250 followed by Grandioso heavy flow and Herculite enamel, the lowest composite regarding enamel wear was CAPO which is claimed by the manufacturer to be enamel friendly. These results could be attributed to differences in filler particle size distribution, filler composition, filler loading and degree of crosslinking of the matrix and its physical and mechanical properties[16]. Composites that showed high opposing enamel wear had large fillers of high hardness while composites that showed minimal opposing enamel wear (CAPO) had softer fillers (Barium glass fillers).

From the results of in vitro investigations on the wear behaviour of dental enamel, it can be inferred that enamel is a unique, biocomposite that wears by brittle fracture and/or surface delamination under sliding motion.[35] in the current study the pattern of enamel wear as indicated by SEM results showed fatigue cracks, brittle fracture and surface delaminations of enamel. Generally, the wear behaviour of composite can be associated with either material or clinical factors. Material factors relate to the characteristics, content, and distribution of filler, the degree of conversion and interfacial bond between matrix and filler. In addition, the silane coupling, the nature of matrix and surface hardness also influence the wear resistance of composite materials[20]. Condon and Ferracane, 1997[9] investigated the effects of compositional factors including the degree of cure, filler level and silanation level on the wear resistance of three different experimental composites. The authors found that greater composite wear was correlated with lower filler levels and reduced percent of silane-treated fillers. In the current study the wear result showed variability in the wear results of the used composites could be attributed to the above mentioned factors. Another important key factor in composite wear is curing characteristics and degree of conversion of the matrix, Ferracane et al, 1997[36] demonstrated a strong negative correlation between the degree of cure and the wear of the same experimental composites. It was suggested that longer curing time caused the polymer network to be more highly crosslinked, and therefore more resistant to the forces of abrasion. The different materials used in this study were ensured for proper curing as indicated by manufacturers instructions.

Within the limitations of this in vitro study it could be concluded that:

1. The different composite formulations have different wear rates.
2. Ultrafine microhybrid composite has more wear resistant, while the heavy filled flowable composites has less wear resistant than other types of composites
3. Antagonistic enamel wear must be considered as it is independent of composite wear, some materials were antagonist conserving while others were antagonist aggressive.

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