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Enamel Quality after Debonding: Evaluation by Optical Coherence Tomography

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The aims of this study were to evaluate quantitatively the enamel fractures, adhesive remnants and bracket fragments on enamel after debonding of metal and ceramic brackets, and to quantify the layer of adhesive remnants in depth after two different cleanup procedures. Metal and ceramic brackets were bonded on 120 human incisors and then debonded using two different techniques with Side Cutter (SC) and Anterior Bracket Removal plier (ABR). After this, a high-speed tungsten carbide finishing bur or a low-speed tungsten carbide finishing bur was used. The debonded samples were submitted to enamel assessment with optical coherence tomography (OCT). In sequence, two different methods of removing the remaining adhesive (tungsten carbide burs at high and low speed) were performed and at the end of these procedures, the remaining adhesive layer was measured with OCT. The results demonstrated that enamel fractures were observed only in the samples bonded with ceramic brackets, and the type of pliers did not influence the incidence and extent of enamel damage. Moreover, the type of debonding technique (with side-cutting pliers or anterior bracket removal pliers) and the type of bracket did not influence the amount of adhesive remaining after debonding. The burs at low speed removed the remaining adhesive more effectively during cleanup procedures.

Key Words: dental debonding, enamel, orthodontic brackets.

Introduction

The most used techniques for debonding brackets include the use of pliers that rely on a combination of tensile and shear forces that produce three types of failures: 1) adhesive failure between the adhesive and the base of the bracket; 2) adhesive failure between the adhesive and the enamel; and 3) cohesive failure between the molecules of the adhesive layer (1-4).

Debonding evaluations are most often performed using optical microscope, atomic force microscopy and scanning electron microscope. However, all these techniques perform only surface analysis. Optical Coherence Tomography (OCT) is a low-coherence interferometric technique that provides high resolution, non-invasive, cross-sectional (2D) and volume (3D) tomographic images of tissue microstructures. It is analogous to ultrasound techniques but uses light instead of sound waves to generate biological tissue images (5).

OCT has been widely used for medical purposes, mainly in ophthalmology (6). In dentistry, this technology has been applied to the anatomical characterization of dental and periodontal structures (7), detection of incipient caries (8), evaluation of dental materials (9), qualitative marker of biofilm formed around the brackets (10) and evaluation of periodontal ligament responses to orthodontic forces (11). OCT was used in a previous study (12) for a qualitative assessment of enamel structure after debonding orthodontic brackets and after removing the remaining adhesive. However, there are no reports in the literature on the use of OCT for a quantitative assessment of the enamel structure after debonding orthodontic brackets and after removing the remaining adhesive.

Therefore, the aims of this study were: 1) to evaluate quantitatively the enamel fractures, adhesive remnants and bracket fragments on enamel after the debonding of metal and ceramic brackets; and 2) to quantify the layer of adhesive remnants in depth after two different cleanup procedures.

Material and Methods

The experimental procedure using human teeth was approved by UESB's Ethics Committee and carried out in accordance with the ethical guidelines for research with human participants.

Tooth Specimens

A total of 120 extracted human incisors acquired from a tooth bank of and free of caries, cracks, abrasions and staining (assessed by visual and OCT examination) were selected and stored in a 0.1%thymol solution. The teeth were not subjected to any chemical or orthodontic treatment. The teeth were randomly divided into four groups (n=30) according to the type of bonded brackets and the pliers used for debonding. After debonding, each group was subdivided into two subgroups (n=15) and for each subgroup, a different procedure was used for removal of the adhesive remnants: low-speed and high-speed tungsten carbide finishing bur.

Bonding Procedure

Before the bonding procedure, the anterior surface of each tooth was examined by OCT (Ganymede/Thorlabs, Newton, NJ, USA) in a 3D and 2D mode to exclude samples with any type of enamel damage. Then, for bonding of orthodontics appliances, metallic brackets\Edgewise standard (American Orthodontics, Sheboygan, WI, USA) and ceramic brackets\Edgewise standard (Morelli, Sorocaba, SP, Brazil) were used, all with similar mesh. The enamel surfaces were etched with 37% phosphoric acid for 20 s, rinsed with water for 10 s and then air-dried. The bonding procedure was performed using the Transbond Plus Color Change adhesive system (3M Unitek, Monrovia, CA, USA) according to the manufacturer's instructions. The adhesive was light-cured for 20 s on the incisal and cervical side of the bracket using Radii-Cal equipment (850 Mw/cm2) (SDI Inc., Bensenville, IL, USA). The light intensity was calibrated for each polymerization using a radiometer (Demetron, Danburry, CT, USA). After the bonding procedure, the samples were stored in distilled water for 24 h.

Debonding Procedure

Debonding was carried out 24 h after bonding using two different pliers: Side Cutter (SC) (Model i-552; Rocky Mountain Orthodontics, Denver, CO, USA); and Anterior Bracket Removal plier (ABR) (Model E-346; Piramid Orthodontics, Corte Madera, CA, USA). All debonds were made by the same operator. Although variations in the use of these instruments are possible, debonding was performed in a standardized procedure (13), as follows:

The SC was placed diagonally at the bracket base, on the cervical and incisal parts. The bracket was removed by gentle squeezing of the pliers and an additional clockwise rotational movement. (Fig. 1A).

The ABR was applied by gripping below the bracket wings at the bracket-enamel interface. By closing and downward tipping of the pliers, a rotational axis was created at the apical bracket margin, thereby releasing the bracket. (Fig. 1B)

After bracket removal, the teeth were again examined by OCT and 3D volumetric images were obtained (two 3D images for each tooth).

Quantification of the Remaining Adhesive (T1)

Images of the remaining adhesive taken after the removal of the brackets were processed using ImageJ (Version 1.44p, Wayne Rasband National Institutes of Health, USA). With this software, the following measurements were made: 1) adhesive remaining area, 2) enamel fracture area and 3) area of the bracket fragments (generated by bracket fractures during debonding) (Fig. 2). All of these measurements were converted into percentages, according to the following equation:

Area (%) = [Measured area (μm^2)]/[Total bracket base area (μm^2)] x 100

Cleanup Procedure

Adhesive removal was carried out with two different types of burs: a high-speed tungsten carbide finishing bur (Model CF375R; Beijing Smart Technology, Beijing, China) and a low-speed tungsten carbide finishing bur (Model CB27204; Beijing Smart). The cleanup was performed by a single operator, with the bur positioned parallel to the long axis of the teeth and horizontal movements. The procedure was considered complete after visual and macroscopic observation of satisfactory removal of the remnants. A new bur was used for each ten samples. After cleanup, new readings using OCT in a 2D mode (cross-sectional images) were taken.

Quantification of the Remaining Adhesive Layer (T2)

Cross-sectional images (2D) of the remaining adhesive layer after the cleanup procedure were processed with the ImageJ software. The following measurements were made: 1) the greatest depth of the adhesive remaining layer (µm); and 2) the area of remaining adhesive layer (µm2) (Fig. 3).

OCT Observation

In this study, a commercial spectral optical coherence tomography system (Ganymede OCT/Thorlabs) produced

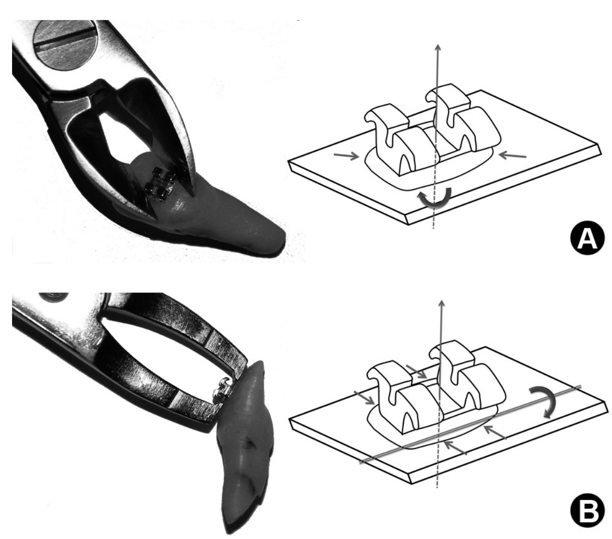

Figure 1. Positioning and forces generated by (A) SC and (B) ABR.

cross-sectional (2D) and volumetric (3D) optical imaging. It is connected to a preconfigured PC and the images are obtained with a scanner probe. The base unit contains the super luminescent diode (SLD) light source. The wavelength of the SLD is centered at 930 nm, with a spectral width of 100 nm. With an A-scan rate of 29 kHz, this system can produce 29 fps with 512 lines per frame and an axial resolution of 5 µm.

Optical Coherence Tomography images were taken to evaluate the surface of the intact enamel before bonding at T0 (2D and 3D), after bracket removal at T1 (3D) and after residual resin removal at T2 (2D).

Statistical Analysis

To identify differences in the mean values of the three measurements at T1, (for variable brackets and pliers) was

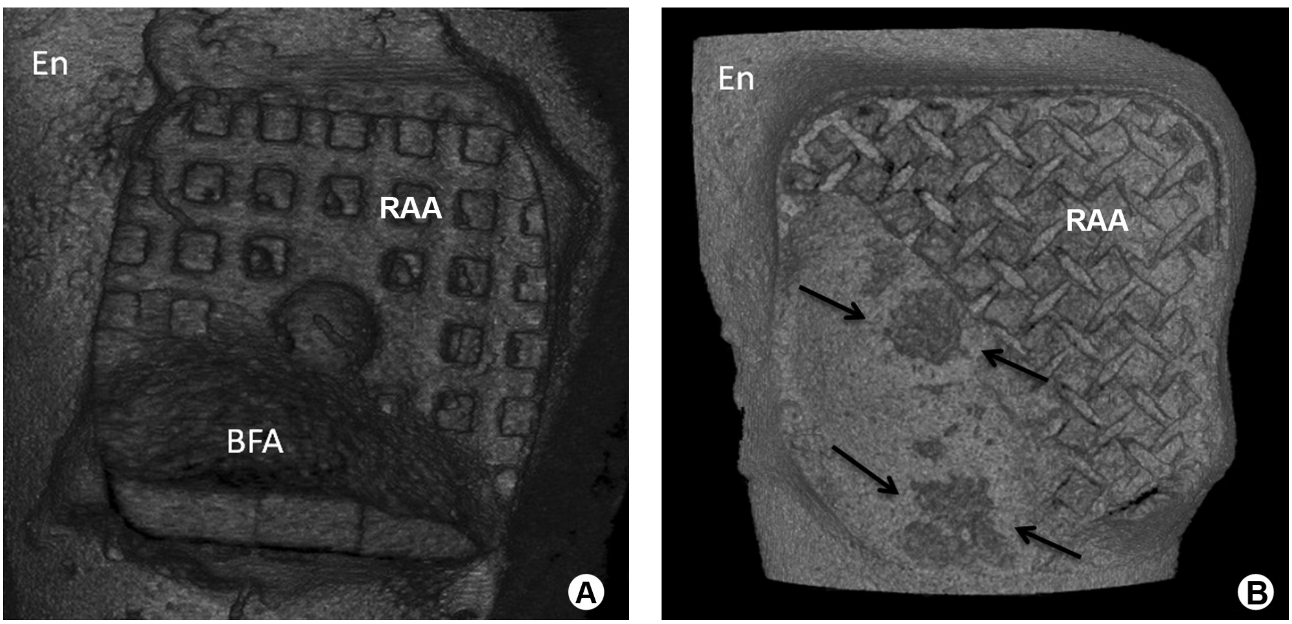

Figure 2. Images obtained for the measurement of variables. remaining adhesive area (RAA), enamel fracture area (arrows), bracket fragment Area (BFA), Enamel (En).

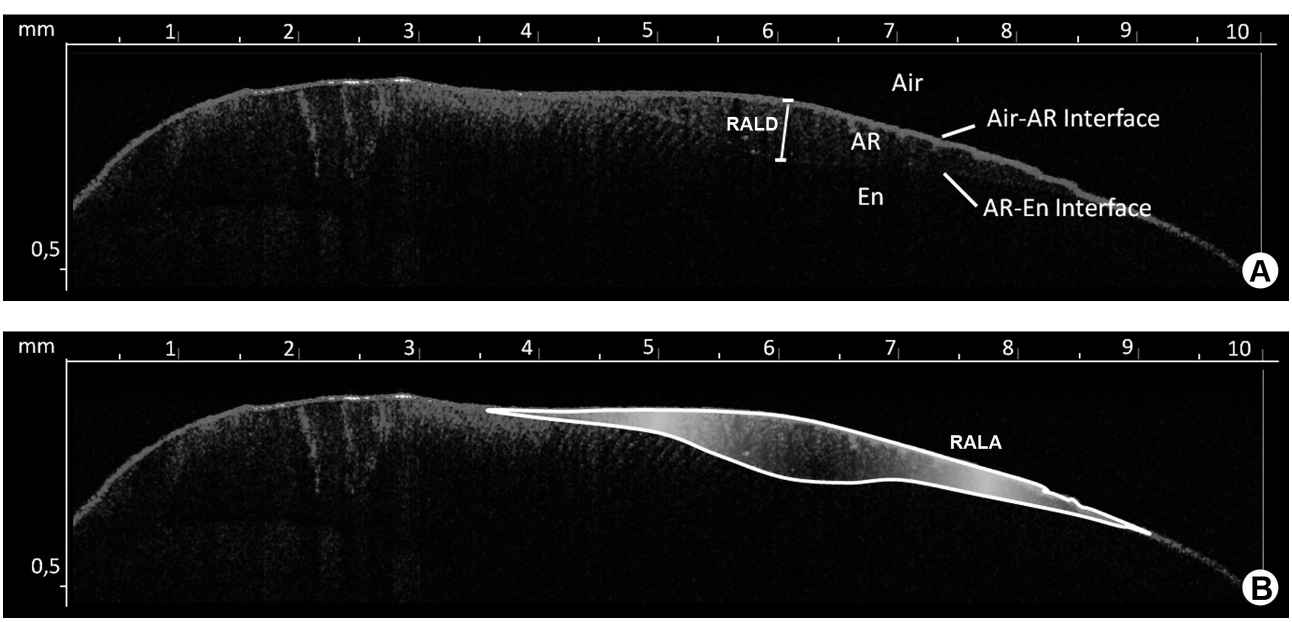

Figure 3. Images obtained for the measurement of variables. Remaining adhesive layer depth (RALD) in 3A and remaining adhesive layer area (RALA) in 3B. adhesive remnant (AR), Enamel (En).

used two-way ANOVA (full factorial design, n=30). The homogeneity of variances among the four groups was tested using the Levene's test. The comparison between groups after ANOVA was performed using the Games-Howell test for heterogeneous variances, because the Levene's test indicated heterogeneous variances for 3 variables.

Chi-square test was used to identify whether there was a statistically significant association between the frequency of enamel fractures and the independent variables (bracket and pliers). The level of significance was set at 5%.

To identify differences in mean depth and the area of remaining adhesive layer at T2 for the different groups, Kolmogorov-Smirnov test was used to assess the normality of the data and Levene's test was used to assess the homogeneity of variances. Because all the treatments were normally distributed, was used two-way ANOVA and full factorial design. Then, the Games-Howell test was used for heterogeneous variances, and the Tukey HSD test for homogeneous variances. The Pearson's linear correlation test was used to compare the behavior of the variables analyzed at T2.

Dahlberg's error test was performed to analyze errors in methodology for all measurements obtained in the present study.

Results

Analysis of Enamel and Quantification of Adhesive Remaining after Debonding (T1)

It was found that although the metal brackets generated smaller amounts of remaining adhesive than the ceramic brackets, regardless of the type of pliers used for debonding, there was no statistically significant difference between them (p>0.05). Likewise, there was no statistically significant difference (p>0.05) between the SC and ABR groups, regardless of the type of brackets. The ABR group values for the area of remaining adhesive were smaller than for the SC group.

It was observed that fractures occurred only in the samples bonded with ceramic brackets and that SC use resulted in a smaller number of fragments. However, there was no statistically significant difference in the area of bracket fragments produced by the use of SC or ABR pliers (p>0.05).

It was observed that the enamel fracture occurred only in samples bonded with ceramic brackets and that SC pliers use resulted in a lesser extent damage to the enamel. However, there was no statistically significant difference in the extent of enamel fractures produced by SC or ABR pliers (p>0.05). Damage to the tooth tissue occurred only after debonding of ceramic brackets. The two debonding techniques produced a statistically similar frequency of enamel fractures (p>0.05).

Depth and Area of the Remaining Adhesive Layer after Cleanup (T2)

After removing the remaining adhesive, it was observed that the use of low-speed burs led to an enamel surface with less adhesive residue when compared to the use of high-speed burs, which was true for both the depth and the area of the remaining adhesive layer (p<0.05). The Pearson's linear correlation test showed a statistically significant correlation (p<0.05, r=0.7662) between the measured values (depth and area), indicating that these two parameters can be used to quantify the remaining adhesive layer (Fig. 4 and Table 1).

Discussion

The debonding of brackets is a procedure with risk of damage to the enamel in the form of cracks, scratches or tissue loss. The key to preservation of this tissue may be the use of techniques that prevent the development of adhesive failures at the enamel-adhesive interface, leaving as much adhesive on the tooth surface as possible. Knosel et al. (2010) and Zachrisson et al. (1980) (13,14) observed that maintaining the structural integrity of enamel after debonding coincides with the presence of larger quantities of remaining adhesive.

Both pliers evaluated in this study generated large amounts of remaining adhesive for the SC and ABR (Fig. 1) groups. The amount of remaining adhesive was not significantly different after the use of both pliers (p>0.05), a result which is in agreement with the study by Knosel et al. (2010) (10). These observations suggest that both SC and ABR pliers may be used for debonding. SC and ABR pliers are relatively safe for dental tissues because the high amounts of adhesive remnants generated by both

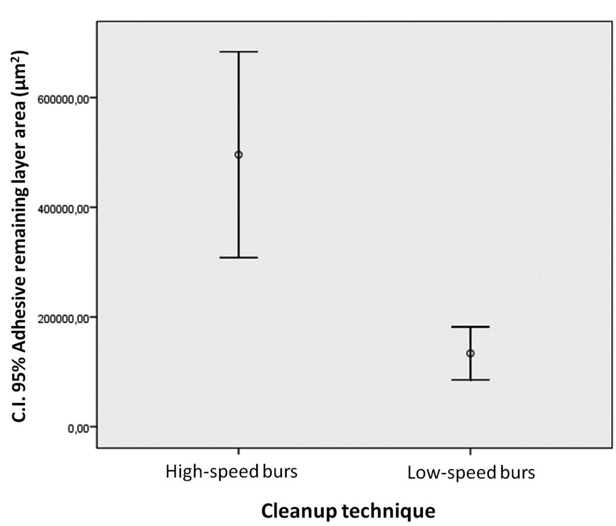

Figure 4. Confidence intervals and the mean remaining adhesive layer area (µm2) after cleanup.

of them indicate adhesive failure at the bracket-adhesive interface. However, contrary to these findings, Zarrinnia et al. (1995) (15), examining a small sample (n=6) found that ABR produces failures at the bracket-adhesive interface, while SC produces failures at the enamel-adhesive interface.

The debonding of ceramic brackets occurs mainly because of failure at the enamel-adhesive interface (16). Additionally, in most cases the debonding of metal brackets leads to a failure at the interface between the adhesive and the bracket base (1). In the present study, the type of bracket (metal or ceramic) did not influence significantly the amount of remaining adhesive on enamel after debonding (p>0.05), indicating that there is a higher incidence of failure at the adhesive-bracket interface for both types of brackets.

The ceramic brackets are extremely brittle and, therefore, a small amount of energy may be enough to fracture them (17). Clinically, a bracket fracture during debonding is undesirable because the presence of ceramic fragments on the tooth hampers the polishing of enamel (18). In this study, it was found that both SC and ABR pliers produced statistically similar amounts of ceramic fragments on enamel after debonding procedures (p>0.05).

In this study, it was found that enamel fractures occurred only during the debonding of ceramic brackets, revealing a greater risk of damage from this procedure compared to the debonding of metal brackets. This can be explained by the fact that the composite adhere strongly to the ceramic bracket mesh. A previous study (19) indicated higher possibility of enamel fractures after the debonding of ceramic brackets, which relates to the strong adhesion of ceramic brackets to enamel.

It was observed also that the type of pliers used for debonding did not significantly affect both the extent and the frequency of damage to enamel, because there were no statistically significant differences between the area and frequency of damage produced by SC or ABR pliers (p>0.05). These results are in agreement with Knosel et al. (13) who observed no statistically significant difference (p>0.05) in the incidence of enamel fractures after using ABR or SC pliers. This can be explained by the fact that the removal of all brackets was performed by an experienced orthodontist.

Although many studies (15,17) have evaluated the characteristics of enamel surface after cleanup procedures, no studies have analyzed the thickness of the remaining adhesive layer after cleanup. In this study, the measurement of the adhesive remnants layer depth was possible with the use of OCT.

It was found that the use of burs at low speed removes more effectively the remaining adhesive compared to burs at high speed because both the depth and the area of the remaining adhesive layer were significantly lower after the use of low-speed burs (p<0.05). Bishara et al. (17) report that cleanup with low-speed burs is a safer procedure because it involves less enamel loss than high-speed burs.

From analysis of the tooth structure with OCT after debonding and cleanup procedures, the following observations were made:

Areas of enamel fractures and bracket fragments were observed only in samples bonded with ceramic brackets. The type of pliers (SC or ABR) did not influence the amount of ceramic fragments or the extent/incidence of enamel damage; moreover, the type of pliers (SC or ABR) or used brackets (metal or ceramic) did not influence the amount of adhesive remaining on enamel after debonding. The results from the present study are of great clinical importance, and directs the orthodontist to use maneuvers to

Table 1. Games-Howell multiple comparison test for remaining adhesive on the enamel (%), according to brackets (metal and ceramic) and pliers (SC and ABR)

(I) Bracket x Plier	(J) Bracket x Plier	Mean difference	Standard error	p value	95% confidence interval	
					Lower bound	Upper bound
Metalic/ SC	Metalic/ABR	8.3467	6.0054	0.5113	-7.5884	24.282
	Ceramic/SC	-1.8123	3.8145	0.9641	-12.036	8.4109
	Ceramic/ABR	2.501	5.2726	0.9644	-11.452	16.454
Metalic/ ABR	Metalic/SC	-8.3467	6.0054	0.5113	-24.282	7.5884
	Ceramic/SC	-10.159	5.1328	0.2153	-24.006	3.6876
	Ceramic/ABR	-5.8457	6.2925	0.7895	-22.511	10.82
Ceramic/ SC	Metalic/SC	1.8123	3.8145	0.9641	-8.4109	12.036
	Metalic/ABR	10.159	5.1328	0.2153	-3.6876	24.006
	Ceramic/ABR	4.3133	4.252	0.7421	-7.1133	15.74
Ceramic/ ABR	Metalic/SC	-2.501	5.2726	0.9644	-16.454	11.452
	Metalic/ABR	5.8457	6.2925	0.7895	-10.82	22.511
	Ceramic/SC	-4.3133	4.252	0.7421	-15.74	7.1133

facilitate the removal of ceramic brackets bonded with materials with lower adherence like reinforced resin glass ionomer cements.

Resumo

Os objetivos deste artigo foram avaliar quantitativamente a presença de fraturas de esmalte, adesivo remanescente e fragmentos de bráquetes no esmalte após a descolagem de bráquetes metálicos e cerâmicos e quantificar a camada de adesivo remanescente após a realização de diferentes procedimentos de limpeza. Bráquetes metálicos e cerâmicos foram colados em 120 incisivos humanos e descolados usando duas técnicas diferentes: com alicate de corte (SC) e alicate removedor de bráquete (ABR). Após isso, brocas de carboneto de tungstênio em alta ou baixa velocidade foram utilizadas. As amostras de esmalte foram então submetidas à avaliação com tomografia de coerência óptica (OCT). Na sequência, foram realizados dois métodos diferentes de remoção do adesivo remanescente (brocas de carboneto de tungsténio em alta e baixa velocidade), e no final destes procedimentos, a camada de adesivo remanescente foi medida com OCT. Os resultados demonstraram que as fraturas de esmalte foram observadas apenas nas amostras coladas com bráquetes cerâmicos e o tipo de alicate não influenciou a incidência nem a extensão dos danos ao esmalte. Além disso, o tipo de técnica de descolamento com alicate de corte ou alicate de remoção de bráquetes e o tipo de bráquete não influenciaram a quantidade de adesivo remanescente após a descolagem. O uso de brocas em baixa velocidade mostrou-se mais efetivo na remoção do adesivo remanescente durante os procedimentos de limpeza.

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