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Comparative Study of Different Cavity Configuration Effect on Marginal Adaptation of Bulk Fill Versus Conventional Resin Composites

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ABSTRACT

Aim : The aim of the study is to evaluate the effect of different cavity configuration (C-factor) on marginal adaptation of Sonic fill versus Ceram X conventional composite resin composites. **Subjects and methods** :A total of 90 freshly extracted human non carious premolar teeth was used and divided randomly according to tested materials into two main equal groups (45 each); Sonicfill and Ceram X resin composites. Each group was further divided according to the cavity configuration into three equal subgroups of (15 each); flat tooth surface, class II cavity and class V cavity. Each subgroup was divided subdivisions according to storage time into three (5 each); one month, three months and six months. After storage time and dye immersion in silver nitrate 50% wt for 12 hours. Each tooth was splatted longitudinally into 2 halves and inspected under stereomicroscope to evaluate the marginal leakage of tooth restoration interface. Finally, a randomly representative specimen from each group was investigated under Scanning Electron Microscope (SEM) to evaluate the qualitative examination. **The results** of this study revealed that less microleakage of Sonic-fill than Ceram X. C-factors do not completely eliminate the microleakage with both bulk fill resin materials. There was significant difference between flat tooth surface and both of classII and classV. Sonicfill and Ceram X showed high leakage score at six months storage time.

KEYWORDS

Cavity Configuration, Marginal Adaptation, bulk fill, conventional Resin Composites, leakage.

INTRODUCTION

Resin composites were introduced as aesthetic materials for anterior restorations and their use was quickly extended to posterior teeth. Despite the evolution of composite resins and the improvement of the adhesive systems, composite restorations still present some drawbacks. One of the major drawbacks is polymerization shrinkage, which consequently leads to the generation of polymerization stress that may causing debonding between tooth structure and resin composite leading to marginal discoloration and secondary caries that can reduce the longevity of the restoration. [(1)]

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Moreover, these stresses may transfer into the tooth structure and can cause micro-fractures and cusp deflection. Many efforts have been made in order to reduce the volumetric shrinkage of composite resins, one of them is the chemical formulation of some materials [2].

Microleakage is one of the most frequent problems associated with resin composites. Lack of sealing allows the occurrence of marginal gap at tooth restoration interface. Polymerization stresses are generated within the restoration and at the margins, and if these stresses exceed the bond strength microleakage may occur at the tooth restoration interface [3]. Factors that influence stress formation includes volumetric polymerization shrinkage, elastic modulus and flow of the resin composite, adherence of the resin composite to the cavity walls and the configuration factor of the restoration. [4]

Cavity configuration factor (C-factor); ratio of bonded to unbonded surface area in the cavity. The increase in C-factor is associated with progressive weakening of the bond strength. Therefore, the strength of the adhesive interaction with tooth structure should be able to counteract the generated polymerization stresses in the resin composite and at the interface. Otherwise, there can be a deleterious effect on marginal integrity and gap formation. [5] The magnitude of contraction stresses is highly dependent on the viscoelastic properties of the material [6]. Clinically, these stresses may be transferred to the margins of the restoration, possibly affecting marginal quality [7]. When marginal quality is not adequate, problems like leakage, recurrent caries and pulpal irritation may occur [8,9].

To avoid the clinical consequences of polymerization shrinkage, incremental filling techniques are usually preferred over the bulk filling method to obtain effective marginal seal [10]. Although incremental technique may be important for adequate light penetration, its disadvantages are the possibility of trapping voids between layers and the time required to place the restoration [11]. Bulk application technique is simpler, and it makes the work quicker by reducing the number of clinical steps [12].13 Despite the developments in adhesive systems, significant advances in composite technology are not so frequent. In this context, a group of products was recently introduced, the so called ‘bulk fill composites[13].

These materials are suitable for insertion in a 4 mm bulk placement due to their reduced polymerization stress and their high reactivity to light curing. Depending on the material, this layer should be covered by a layer of standard composite [14,15].

The aim of the present study is to determine the marginal adaptation of contemporary bulk-fill composites in different cavity configurations in comparison to conventional composite. The null hypothesis tested was that there would be no differences in marginal adaptation in cavities restored with different types of composites.

MATERIALS AND METHODS

Sonicfill Bulk-fill composite

Ceram X conventional composite

Self-etch adhesive (One step); (*4-Methacryloxyethyltrimllitate anhydride5-10%,acetone 30-40%, water15-20%, Dimethacrylat15-20%, phosphoric acid ester monomer15-20%, silicon dioxide 1-5%, photoinitiator*

Methods.

Grouping of the collected teeth:

A total number of 90 freshly extracted human non carious premolar teeth was used and divided randomly according to tested materials into two main equal groups (45 each); Sonicfill (S) and Ceram X (V) resin composites. Each group was further divided according to the cavity configuration into three equal subgroups of (15 each); flat tooth surface (F), class II cavity (T) and class V cavity

(F). Each subgroup was divided according to storage time into three subdivisions (5 each); one month (1), three months (3) and six months (6).

Preparation of specimens for different cavity configuration:

C factor (O); (one bonded surface) A standardized flat tooth surface were prepared in 30 teeth by creating a depth cut grooves of 2mm at the occlusal surface of premolar. These grooves were united to create a flat tooth surface (the bur was replaced after 3 preparations). **C factor (T)**; (3 bonded surfaces) A standardized Class II MOD cavity without any axial step prepared in 30 teeth with Bucco-lingual width occlusally (2mm) in the middle 1/3 [rd.] of the cusp tip of the teeth. The cavity depth was 2 mm. **C factor (F)**; (5 bonded surface) Standardized class V cavities were prepared on buccal surface of 30 teeth. The outline of each preparation was prepared by using window matrix give class V shape. The dimension 2×2×2mm (mesio-distally, depth and occluso-gingivally) with the gingival margin at least 1.0 mm above the CEJ.

The preparation was done by using carbide burs in high-speed handpiece with profuse water-coolant were used to carry out all preparations. A new bur was used for every three cavity preparations to maintain cutting efficiency and using graduated periodontal probes to confirm the dimensions.

Application of adhesive system; The bonding procedures was done by using G-aenial self-etch adhesive system according to the manufacturers' instructions.

Application of resin composite.

1. *Application of Sonic fill composite:* starting from the bottom of the cavity until complete filling of the cavity using Sonic-fill handpiece (Kerr Corporation, Orange CA 92867, U.S.A). the handpiece was used under air pressure between 30-50 psi (~2-3.4 Bar), The middle speed for the application was used (where No.1 is the slowest, No.5 is the fastest).
2. *Application of* Ceram X: In the present work, Ceram-X was applied in a 4 mm increment to establish the same conditions for all groups. A high intensity light curing unit was employed so it was expected to have an adequate degree of conversion of the material in this thickness.

Storage of specimens: After restorative procedures the teeth were stored in water at 37°C in an incubator with 100% humidity at different storage time (one day, three months and six months) until they were tested. Through the period of storage time the specimens were thermocycle between 5 °C and 55 °C for 100 cycles (one minute for each).

Test methods:

1- Microleakage evaluation:

Sealing of teeth:

At the end of each aging period, the teeth were removed from the water and dried with oil free air. Then a small soft brush was used to coat the crown and the root of each tooth with clear nail varnish except for the restoration away 1mm all around the margins of the cavity, the nail varnish was left to dry completely. Also, a second layer of varnish was applied to ensure complete sealing of all other surfaces of the tested specimens and lifted to dry [(16)].

Dye penetration technique:

The specimens were immersed in an aqueous solution of 50wt% ammoniacal silver nitrate (pH 9.5) for 24 h, followed by 8h in a photo-developing solution, to permit the reduction of di-ammine silver ions to metallic silver grains. The specimens were removed from the photo-developing solution and washed in running water for 2min. Then the specimens were dehydrated in ascending concentrations of ethanol as follows: 25% for 20min, 50% for 20min, 75% for 20min, 95% for 30min, and 100% for 60 min [(17)].

Sectioning of specimens:

Teeth were sectioned longitudinally in buccolingual direction through the middle of the restoration for classV and flat dentin specimens with water coolant using a fin diamond disc at low speed. While for classII MOD specimens the sectioning were in mesiodistal direction through the middle of the restoration [18].

2- Microscopic examination and microleakage assessment (quantitative examination):

Both halves for each tooth were examined under stereomicroscope at X 25 magnification. The extent of dye at the tooth restoration interface for all specimens in each group were evaluated [19].

The degree of dye penetration was assessed by using a modified scoring system [20] according to the following criteria

Score 0 = No dye penetration

Score 1 = Dye penetration along enamel wall only.

Score 2= Dye penetration along enamel and extend up to1mm in dentinal wall.

Score 3= Dye penetration along enamel and extend 2mm in dentinal wall for flat tooth surface and for class II, while extend along the entire length of the cervical floor of classV.

Score 4= Dye penetration up to the dentin bridge more than 2mm in dentinal wall for flat dentin and classII, while extend along the entire length of the cervical floor and one-half of the axial wall of classV.

Scanning electron microscope examination (SEM) (qualitative assessment):

One representative specimen from each group (randomly selected) were used for SEM analysis. The holder with the specimen in place was mounted in scanning microscope. The surfaces of specimens were examined under scanning electron microscope at 7 KV. Photomicrographs were taken at magnifications X1500 to demonstrate the tooth/restoration interface[21].

RESULTS

1 - Effect of the restorative material types on microleakage table (1)

A - In C1 (Flat tooth surface) groups:

There was no significant difference in Sonicfill bulk fill and Ceram X resin composite at all storage times but without significant difference between them.

Where ***at one month,*** the mean leakage score value (0.45±0.06) of Ceram X was higher than the mean leakage score value (0.35±0.02) of Sonicfill. Also

At 3months, the mean leakage score value (1±0.6) of Ceram X was higher than the mean leakage score value (0.88±0.05) of Sonicfill without significant difference between them where p-value = (0.03).

At 6months, the mean leakage score value (1.3±0.4) of Ceram X was higher than the mean leakage score value (1±0.03) of Sonicfill specimens with no significant difference between them where p-value = (0.02).

B- In C3 (ClassII) groups:

At one month, the mean leakage score value (1.05±0.4) of Ceram X specimens was higher than the mean leakage score value (0.90±0.5) of Sonicfill specimens with no significant difference between them where p-value= (0.2).

At 3months, the mean leakage score value (1.8±0.4) of Ceram X specimens was higher than the mean leakage score value (1.55±0.1) of Sonicfill specimens with no significant difference between them where p-value = (0.04).

At 6months, the mean leakage score value (2.1±0.5) of Ceram X specimens was higher than the mean leakage score value (1.85±0.3) of Sonicfill specimens' value without significant difference between them where p-value = (0.01).

C - In C5 (ClassV) groups:

At one month and at 3months, the mean leakage score value (1.55±0.05) (2.19±0.7) respectively of Ceram X specimens was higher than the mean leakage score value (1.45±0.3) (1.84±0.09) respectively of Sonicfill specimens with no significant difference between them where p-value= (0.1) (0.3) respectively.

At 6months, the mean leakage score value (2.40±0.5) of Ceram X specimens was higher than the mean leakage score value (2.10±0.6) of Sonicfill specimens' value with no significant difference between them where p-value= (0.4).

Table (1) ***The mean leakage score, standard deviation (SD) and p-values of*** *Ceram X and Sonicfill bulk fill* ***resin composite under the effect of C-factors at different storage times.***

C-factor	Restorative materials Storage time	S Sonicfill Mean ± SD	X CeramX Mean ± SD
O Flat dentin	O1	0.35±0.02	0.45±0.06
	p-value	0.01	
	O3	0.88±0.05	1±0.6
	p-value	0.03	
	O6	1±0.04	1.3±0.4
	p-value	0.02	
T ClassII	T1	0.9±0.5	1.05±0.4
	p-value	0.2	
	T3	1.55±0.1	1.8±0.4
	p-value	0.04	
	T6	1.85±0.3	2.1±0.5
	p-value	0.01	
F ClassV	F1	1.45±0.3	1.55±0.05
	p-value	0.1	
	F3	1.84±0.09	2.19±0.7
	p-value	0.3	
	F6	2.10±0.7	2.40±0.8
	p-value	0.4	

Configuration factor on microleakage figure (1); there was significant difference between Ceram X and Sonicfill resin composite in all C-factor. Where in flat dentin (O) the mean leakage value (0.53±0.07) for Ceram X was higher than the mean leakage value (0.36±0.05) for Sonicfill where p-value (0.001). While in Class II (T) and Class V (F) the mean leakage value (1.52±0.7) and (1.95±0.7) respectively for Sonicfill was lower than the mean leakage value (1.74±0.9) and (2.12±0.1) respectively for Ceram X where p-value (0.001).

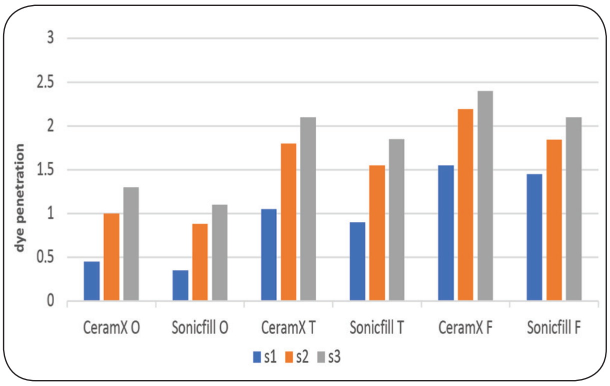

Fig. (1) Bar chart representing of the effect of C-factor for restorative material regardless the other variables.

2- Effect of storage time on microleakage figures (2); There was no significant difference between the mean leakage value (0.90±0.09) of Sonic fill at one month and (0.92±0.09) of Ceram X at one month where p-value (0.2). Also, at three months no significant difference between the Sonic fill and Ceram X While a statistically significant difference was found between the mean leakage value (1.70±0.6) of Sonic fill at six months and the mean leakage value (1.83±0.6) of Ceram X at six months where p-value (0.04).

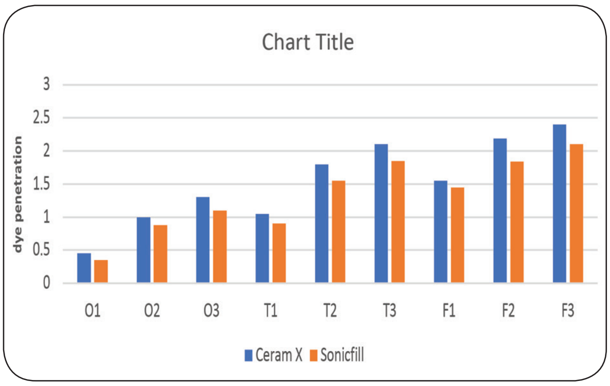

Fig. (2) Bar chart representing the effect of storage time on restorative materials

Scanning Electron Microscope observations: -

Scanning Electron Microscope (SEM) was used to determine the marginal gap as it provides high resolution electron micrographs, and it can provide a more accurate picture of the marginal leakage [22]. The two main established methods that are usually used to study marginal gaps are either dye penetration or SEM. In dye penetration testing the sample is subjected to a dye marker using silver nitrate where it has extremely small diameter that is more penetrative than other types. So, it is more appropriate for detecting of nano-porosities within the hybrid layer [23].

With respect to the SEM requires extensive chemical preparations that may lead to alteration or destruction of the interfacial zones, and even underestimation of the actual thickness of the hybrid layer [24]. The following representative SEM photograph (at 1500X) which only has leakage were obtained at the end of each storage period

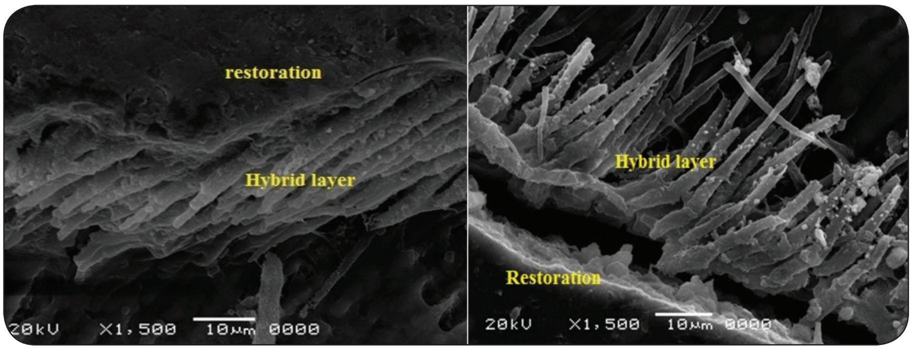

Fig. (3) Scanning electron photomicrograph for the resin dentin interface (at 1500X) of Sonic fill at 6 months storage showing gap at the interface (left) and for the resin dentin interface (at 1500X) of Ceram X at six months storage showing gap at the interface (right).

DISCUSSION

In this study, two types of resin composites were used with their adhesive systems (Sonic fill and categorized as a low shrinkage bulk fill resin composite and the other is Ceram X conventional composite).

The adaptation at the resin-cavity interface is greatly influenced by the amount of polymerization shrinkage and also could be affected by increasing the number of cavity walls (C-factor) [10] Three C-factors; (O; flat dentin, T; class II MOD cavity and F; classV) representing less and high bonded surfaces, were used in this study.

1- Effect of cavity configuration (C-factor) on microleakage.

The results of this study demonstrated that all materials under investigation exhibited satisfactory marginal adaptation before aging, Unfortunately, the level of marginal adaptation was not maintained after aging. Ceram X produced the worst results for dentine marginal adaptation. Stresses generated during polymerization shrinkage of composites have potential to cause an adhesive failure or microcracking of restorative material and/or enamel. If adhesion is maintained after contraction stress following placement, deformation of tooth structure or material will occur. If adhesion is not strong enough, gaps will be formed.

The data of the current study revealed that tested materials do not completely eliminate the microleakage with all C-factors. This could be attributed to the fact that the volume of polymerization shrinkage of new bulk fill resin composites used in this study were still more than the stresses created at the margin of the restoration regardless the effects of the number of bonded cavity walls (C-factor) [25]. The compensation of polymerization shrinkage by relaxation of the resin monomers is still significantly restricted by increasing C factor [26]. This explains the presence of leakage even with lower bonded surface of C-factor O related to C-factor F for all groups with no significance between them.

Flat dentin (O) showed less leakage in all tested groups. This may be explained by the fact that the wall-to-wall shrinkage with one bonded surface was decreased and the chance for gap formation was subsequently decreased. Where, the composite relaxation provided by the unbonded surface was more efficient for decreasing and relieving the shrinkage stresses generated during the polymerization reaction [(27)]. On the same basis, the leakage score of F was higher than T which included less bonded surface.

These results are agreement with ***da Silva et al*** [(28)] who stated that cavities with a low C-factor had lesser marginal gap values than cavities with higher C-factor. When the configuration factor is low the free surface is sufficient to maintain the resin composite-tooth bond as the stress relaxation by flow of resin monomer was allowed by the unbounded surface [(29)].

The finding of this study counteracts the result of ***El-Marhomy et al***, [(30)] which revealed that there is no marginal gap at the dentin-composite interface in the different tested C-factor preparations; this may be due to different in material or methods. Also, the results showed that the leakage in C-Factor F was found to be significantly more than the leakage of C-Factor T which may be described by the unbounded area facilitate composite plastic deformation during polymerization before the gel point is reached, thus reducing the final shrinkage stresses values. Also, high C-factor which has less free surface area to compensate for polymerization shrinkage stress with flow of resin resulted in different dentinal properties, which could affect microleakage. The greater the C-factor the greater the shrinkage and its stress and this situation is worse in considering the application of composites in cavities with high C-factor [(31)].

In view of material wise used in this study and as the results revealed that the high C-factors (F) showed high leakage score of sonic fill bulk fill and Ceram X while low leakage score of sonic fill and Ceram X was obtained from low C-factor (O). This finding was confirmed by the fact that the adaptation at the resin-cavity interface was influenced by the amount of polymerization shrinkage. This shrinkage leads to stresses that not relieved by flow of the material, On the other hand, lower C-factor number (O) allowed more resin composite relaxation that decreased the shrinkage stresses generated during the polymerization reaction leading to less leakage[(32)].

It is known that placement techniques and C-factor are an important factor in the modification of shrinkage stresses and the magnitude of the stress is mediated by the stiffness of the composite, its stress relieving capacity, its curing rate and the constraint applied by bonding to the cavity preparation [(33)].

If the polymerization of composite occurs in an unconstrained condition, the internal stresses will be minimized [(33)]. The incremental and bulk fill techniques have been largely recommended because it is expected to decrease the C-factor [(34)]. A previous study comparing the mechanical properties of bulk-fill composites demonstrated that Venus Bulk Fill has mechanical properties (flexural strength, flexural modulus and Vickers hardness) similar to or lower when compared to all the other bulk-fill composites (Tetric EvoCeram Bulk Fill, Surefil SDR and SonicFill) [(35)].

It has been hypothesized that the elastic modulus is more important than shrinkage in determining the stress [(33,36)]. In this sense, elastic modulus of restorative materials influences their behavior under stress.

Cavity configuration combined with the elastic buffer effect of flowable materials has demonstrated interesting dentine marginal adaptation in class II cavities [(37)]. Considering bulk-fill placement technique, it has been demonstrated that Sonic fill showed better internal adaptation than conventional composites in high C-factor cavities [38].

For direct composite restorations not only marginal adaptation but also adequate polymerization is important to ensure adequate clinical behavior. Degree of conversion may be influenced by material composition (matrix and filler) and translucency, one of them revealed that Surefil SDR, Tetric EvoCeram BulkFill and Venus Bulk Fill exhibited adequate curing at the deepest portion of a 4-mm increment. In general, the claims of the manufacturers about the depth of polymerization bulk-fill composites can be considered reliable [39].

2- Effect of storage time on the microleakage:

The results of the present study revealed that all resinous materials have relative better marginal adaptation at one month storage time. The better marginal adaptation at this period of water storage may be due to the short time that lapse of water storage or may be due to the strength of the adhesive system itself through this period that led strong hybrid layer, therefore, may resist debonding and give a good marginal seal. The water uptake by resin-based composite occurs as soon as the resin composite is exposed to water and the amount of water uptake is time dependent where it increases by time. The water sorption affects the tooth tissue restoration bond through oxidation, hydrolysis and plasticization [40].

The data showed high leakage score at six months storage time. This might be due to hydrolytic degradation of the resin and collagen fibers in the submicron spaces of the hybrid layer increase with the increased exposure to water. In fact, during long-term water storage, the resin absorbs significant amount of water and consequently swelling of the resin may result in the closure of any space between the bonding resin and dentin surface [41]. Conversely, stresses may simultaneously be induced at the bonding resin-dentin interface, which may pull the collagen fibers into the hybrid layer and resin, leading to tearing along the bonded interface as the collagen fibers become weaker over time from hydrolysis. The increase storage period allows increase water uptake, that lead to increased permeability and increase the hydrolytic degradation of the material [42].

In a comparison between the leakage score of studied groups, the lower microleakage scores was obtained with the Sonic fill which could be attributed to the Sonic fill contains a proprietary rheological modifier that reacts to sonic energy from the handpiece and causes the viscosity to drop 87% during extrusion. This viscosity drop allows the Sonic Fill composite to rapidly flow into the cavity, allowing intimate adaptation of the composite to the cavity walls. It also displays a more gradual viscosity buildup than conventional resin composites when shear stress is removed [43].

Certain flowable composites with low elastic modulus are effective to reduce stress, probably by partially absorbing the composite shrinkage strain [44]. The higher the elastic modulus and the polymerization shrinkage of the composite, the higher the contraction stress.

The high volumetric shrinkage produced by flowable composites may lead to high stress values, but it is possible that their low elastic modulus could reduce the stress buildup and maintain the marginal integrity, However, significant stress relief cannot be guaranteed when flowable composites with elastic modulus of approximately 5 GPa and higher are used [45].

On the basis of defined factors in the prevention of microleakage which are bonding resistance, wetting properties, solvent structure, application properties in dentin adhesive systems and molecular elasticity of restorative materials. Presence of water reduces modulus of elasticity and strength of the bond interface. Water sorption is dependent on hydrophilicity of its constituent monomers [46].

CONCLUSIONS

Under the circumstances of this study, the following conclusions were suggested: Conclusions

1. C-factor significantly affected on the marginal seal.
2. Long term storage in water dramatically increased microleakage.
3. The type of restorative material is significantly affected the marginal adaptation.

RECOMMENDATIONS

Long–term (more than 12 months) and clinical studies are required to confirm these findings.

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دراسة مقارنة لتأثير تكوين التجويف المختلف على التكيف الهامشي للملء بالجملة مقابل مركبات الراتينج التقليدية

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الملخص:

الهدف: الهدف من الدراسة هو تقييم تأثير التكوين التجويفي المختلف (C-FACTOR) على التكيف الهامشي لمركب سونكفيل مقابل مركبات الراتنج المركب التقليدية سيرام اكس.

المواد والطرق: تم استخدام ما مجموعه 90 ضاحكًا بشريًا حديثًا تم خلعها حديثًا وقسمت عشوائياً وفقًا للمواد المختبرة إلى مجموعتين رئيسيتين متساويتين (45 لكل منهما) . تم تقسيم كل مجموعة وفقًا لتكوين التجويف إلى ثلاث مجموعات فرعية متساوية (15 لكل مجموعة) ؛ سطح أسنان مسطح وتجويف من الدرجة الثانية وتجويف من الفئة الخامسة. تم تقسيم كل مجموعة فرعية إلى أقسام فرعية وفقًا لوقت التخزين إلى ثلاثة (5 لكل مجموعة) ؛ شهر وثلاثة أشهر وستة أشهر. بعد وقت التخزين والصبغة الغمر في نترات الفضة 50٪ بالوزن لمدة 12 ساعة. تم رش كل سن طوليًا إلى نصفين وفحصها تحت الجهر الفراغي لتقييم التسرب الهامشي لواجهة ترميم الأسنان. أخيرًا، تم فحص عينة تمثيلية بشكل عشوائي من كل مجموعة تحت الجهر الإلكتروني الماسح لتقييم الفحص النوعي.

النتائج: أوضحت نتائج هذه الدراسة أن التسرب المجهري هو الأقل في مجموعة سونكفيل من سيرامفيل. وكذلك عامل سى لا تقضي تمامًا على التسرب الدقيق مع كل من مواد راتنج الملء بالجملة.

الاستنتاج: كان هناك فرق إحصائي بين كلا من الصنف الثاني والصنف الخامس. أظهر كلتا المادتين درجة تسرب أعلى في وقت التخزين لمدة ستة أشهر

الكلمات المفتاحية: تكوين التجويف، التكيف الهامشي للملء، الملأ بالجملة، مركبات الراتينج التقليدية، تسرب.