ORIGINAL ARTICLE

Decoupling with Split-Increment: An Alternative Biomimetic Protocol for Improving Pulpal Floor Adaptation of Direct Large Composite Restorations

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ABSTRACT

When composite resin hardens by light curing, it shrinks and undergoes movement or flow that occurs within each composite increment either towards or away from bonded cavity walls. This behaviour is mainly related to variations in rate and time needed for developing bond strength of adhesive composite to enamel and dentin substrates of surrounding cavity walls.

When the first composite resin increment of 2mm thickness or more is placed and cured over the maturing dentin bond on the pulpal floor in deep occlusal cavities, the shrinkage stresses generated in this increment cause its movement or flow in a direction away from the pulpal floor, and result in debonding within the maturing hybrid layer and formation of internal micro gap. This micro gap is associated with postoperative sensitivity and persistent pain.

The biomimetic protocols of "decoupling with time" and "decoupling with fiber" are well-recognized for direct restoration of large occlusal cavities with incremental composite resins. An alternative protocol of "decoupling with split-increment "is proposed in this paper. This protocol advocates splitting the first composite increment diagonally, prior to light curing. Upon polymerization of the split-increment, it undergoes movement in an outward direction towards the cavity walls rather than movement in a vertical direction away from the pulpal floor. This prevents the incidence of debonding and formation of internal micro gap at the pulpal floor, which subsequently prevents the postoperative sensitivity and persistent pain.

Key words: Decoupling, Hierarchy of bondability, Polymerization dynamics, Shrinkage, Debonding, Diagonal micro gap, Split-increment, Movement, Flow, Postoperative sensitivity, Pulpal floor micro gap, Stress reduction.

INTRODUCTION

Biomimetic restorative dentistry is gaining popularity among dentists in the last decade and is used for placing direct composite restorations. The main goal of using the biomimetic aspects in direct restorative dentistry is to restore the tooth function by strong bonding to dentin and enamel, and to increase the longevity of restorative dental treatments as well as to reduce or eliminate future cycles of retreatment.(1)

The protocols of biomimetic restorative dentistry respect the nature and integrity of the tooth tissues. They are divided into two sets: the stress-reducing and the bond-maximizing protocols. Among the several protocols for stress reduction is the one that advocates reducing the increment thickness of the composite resinin dentin surfaces to be less than 2 mm.(2)

A problem arises when the composite increment is 2mm thick or more; especially the first increment when placed and cured too quickly on the maturing hybrid layer at the

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pulpal floor of deep occlusal cavities. Upon plyrization of this increment, a stressful environment is created where the polymerizingcomposite develops a higher strength of bonding faster than those of the slowly maturing hybrid layer at the pulpal floor, resulting in adhesive debonding and formation of internal micro gaps at pulpal floor (Figure 1).(3)This behaviour could be explained in terms of the two concepts related to biomimetic restorative dentistry: the hierarchy of bondability and the polymerization dynamics.

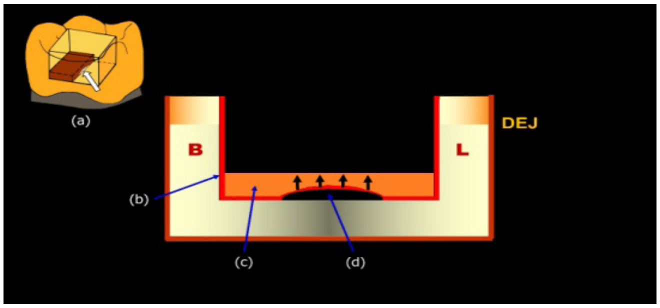

Figure 1: The incremental composite resin filling technique. (a) A sectional view in the first cured composite increment (with ½ increment removed) for illustrating internal micro gap formation at pulpal floor. (b) A dental adhesive system applied on all prepared cavity walls and light-cured. (c) Following the adhesive application, the first increment (2mm or more) of composite resin placed on pulpal adhesive layer and immediately light-cured. (d) Debonding of adhesive interface at pulpal floor and internal micro gap formation.

The main objective of this paper is to present the well-recognized biomimetic protocols used currently for creating large direct composite restorations, and to propose an alternative protocol for improving the pulpal floor adaptation of such restorations. An additional objective is to describe the concepts of the hierarchy of bond ability and polymerization dynamics and to summarize their effects on the adhesive debonding and internal micro gap formation at pulpal floor of large occlusal composite restorations.

The two concepts of hierarchy of bond ability and polymerization dynamics are considered unfavourable for the formation of the hybrid layer at the pulpal floor during their maturation and for achieving successful composite restorations. (4,5)

The first concept of the hierarchy of bondability is related to the bonding capability of enamel and dentin substrates and is based on their mineralization and time taken for bond development. This concept states that the different tooth substrates form different bond strengths. Enamel being the most mineralized and dry substrate forms the highest bond strength, whereas dentin being the least mineralized and moist substrate forms lower bond strength. Additionally, different times are needed for the development of full bond strengths to dentin and enamel, whereas shorter times are needed for developing full bond strengths to enamel substrates, whereas longer times are needed for developing full bond strength to dentin substrates.(4-8)

The second concept of the polymerization dynamics is related to the direction of movement (flow) of the composite resins during polymerization. On polymerization, the generated shrinkage stresses cause polymerizing composite to move, and the direction of such movement is greatly influenced by the volume of the polymerizing mass. (9-12)

The combined effect of these two concepts causes a large polymerizing composite increment (2 mm thick or more) moves away from the hybrid layer resulting in adhesive debonding and formation of internal micro gap at pulpal floor. The consequences of debonding and internal micro gap formation within the hybrid layer at the pulpal floor result in the shift of dentinal fluid into this micro gap. However, this does not occur immediately after curing, but rather after a period of time. The dentinal fluid accumulation in the pulpal floor micro gap is subjected to contraction or expansion with cold or hot stimuli, causing sudden fluid movement in dentinal tubules (Figure 2), and resulting in postoperative sensitivity and persistent pain. Furthermore, the accumulated dentinal fluid causes hydrolysis of adjacent composite resin, resulting in biodegradation of resin-dentin bond over time and failure of this bond.(13-16)

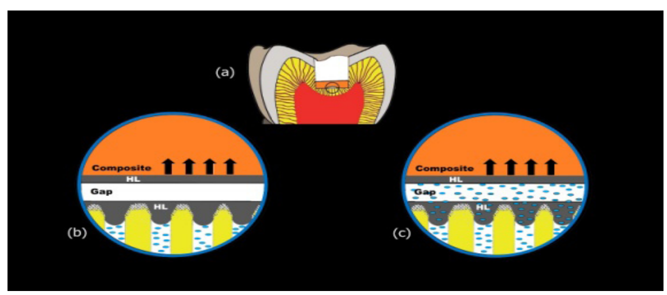

Figure 2: The consequences of debonding and micro gap formation within adhesive interface and hybrid layer (HL) at pulpal floor. (a) A sectional view illustrating the first cured composite increment and the internal micro gap formation at pulpal floor. (b) After a period of time, debonding and micro gap formation within hybrid layer at pulpal floor occur and result in the shift of dentinal fluid into the micro gap. (c) Accumulation of dentinal fluid in pulpal floor micro gap, resulting in post-operative sensitivity and persistent pain.

Several biomimetic direct restorative protocols were introduced for preventing the pulpal floor debonding and internal micro gap formation in large occlusal cavities. These protocols include "decoupling with time" and "decoupling with fiber".

The first protocol of "decoupling with time" neutralizes the combined unfavorable effects of the concepts of hierarchy of bondability and polymerization dynamics. This protocol dictates that polymerization shrinkage stress to the developing dentin bond and hybrid layer should be minimized for a certain period of time (5 minutes) and that the initial composite increment (to be placed over the dentin bond) should be kept to a minimum thickness of less than 2mm (Figure 3). This minimal thickness prevents the connection, or "coupling," of deep dentin to superficial dentin or enamel before the hybrid layer is matured close to its full strength. Immediately after applying the adhesive system, the hybrid layer starts to mature, and the dentin bond begins to develop. However, it takes 5 minutes for the strength of bonding to the hybrid layer and dentin to reach the maximum potential in a stress-free environment without being pulled away from dentin.

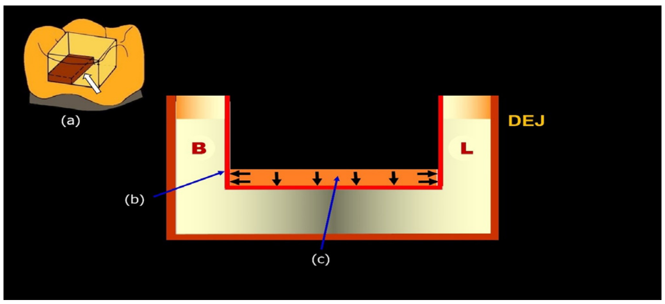

Figure 3: The decoupling with time protocol. (a) A sectional view in the first cured composite increment (with ½ increment removed) for showing absence of internal micro gap formation at pulpal floor. (b) A dental adhesive system applied on all prepared cavity walls and light cured. (c) After waiting for 5 minutes following application and curing of dental adhesive, the first composite increment (not thicker than 1.5mm) placed on adhesive layer at pulpal floor.

In this protocol, a thin layer of composite (not thicker than 1.5mm) is placed over the dentin bond layer following the 5-minute waiting period and spread evenly. During polymerization, the thin composite layer moves towards the developing hybrid layer.

The restoration is completed by placing successive horizontal composite increments (1.5 mm thick each) over the hybrid layer and first composite layer (Figure 4). Each increment is cured separately, without waiting for 5 minutes following light curing of each increment. Application and curing of occlusal composite increment are made for replacing enamel, followed by immediate finishing and polishing with no 5-minute waiting period.(3)

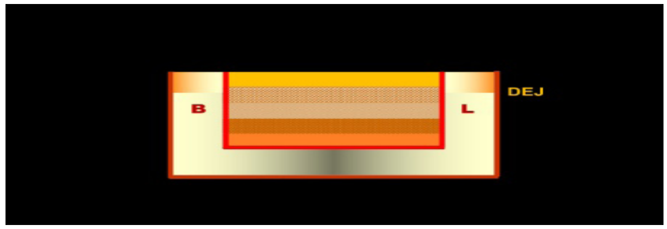

Figure 4: Completion of occlusal composite restoration by placing successive horizontal increments (Not thicker than 1.5 mm each) replacing dentin and occlusal enamel. No required waiting for 5 minutes following curing of each successive increment.

The second protocol of "decoupling with fiber" utilizes a fiber insert for neutralizing the combined unfavorable effects of the concepts of hierarchy of bondability and polymerization dynamics.

In this protocol, an increment of flow able composite (1mm thick) is applied over the cured adhesive layer on the pulpal floor and left uncured. A fiber insert is wetted with uncured dental adhesive resin and left uncured. This uncured combination is pressed in close approximation to the underlying hybrid layer and then cured immediately (no 5-minute waiting time) (Figure 5). Upon polymerization, the fiber insert deforms under the polymerization stress and directs the first composite increment to flow towards all cavity walls (including the pulpal floor), via micro shifting of woven fibers (Figure 6). This allows a stress-free environment for the dentin bond to develop its bond strength at the pulpal floor and the hybrid layer to fully mature. Thus, the use of a fiber insert prevents debonding and formation of internal micro gap within the bonded interface at the pulpal floor. The restoration is completed in a similar way to that followed in the concept of "decoupling with time".(17,18)

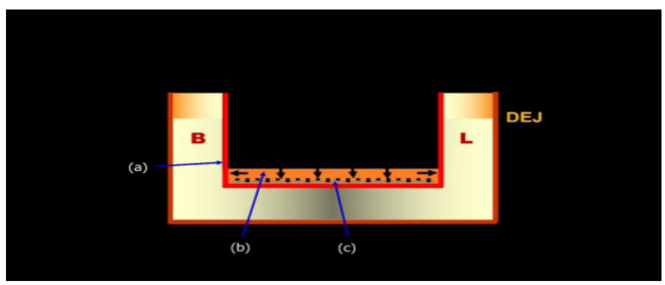

Figure 5: The decoupling with fiber protocol. (a) A dental adhesive system applied on all prepared cavity walls and light cured. (b) The first increment of flowable composite resin (not thicker than 1mm) placed on pulpal floor, and no curing. (c) A fiber insert (0.5mm thick) wetted with adhesive, but not cured and then placed into the uncured flowable resin on pulpal floor. This is followed by curing of the flowable composite increment incorporated with adhesive-wetted fiber insert.

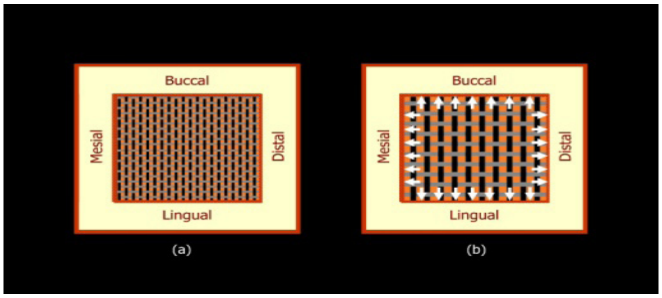

Figure 6: Sectional views showing adhesive-wetted fiber inserted into the flowable composite increment on the pulpal floor. (a) Before curing. (b) Upon curing, movement of small linking masses of flowable composite, via micro shifting of woven fibers, in a direction towards all cavity walls, including the pulpal floor.

The Proposed Protocol

An alternative protocol of "decoupling with split-increment" is proposed in this paper and is utilized for neutralizing the combined unfavorable effects of the concepts of hierarchy of bondability and polymerization dynamics. In this protocol, an adhesive layer is placed on all cavity walls and cured. The first 1.5 mm increment of composite resin is placed over the cured adhesive layer on the pulpal floor and left uncured. The rationale of this protocol is based on creating a 1.5mm wide diagonal micro gap into the first uncured increment and extending vertically into the full thickness of the first increment using a Teflon-coated plastic filling instrument in push stroke (Figure 7).

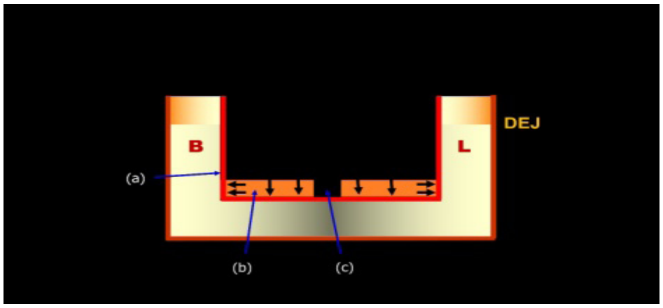

Figure 7: The proposed protocol of decoupling with split-increment. (a) A dental adhesive system applied on all prepared cavity walls and light-cured. (b) The first increment of composite resin (Not thicker than 1.5mm) placed on pulpal floor, and not cured. (c) A 1.5mm wide diagonal micro gap created in the first uncured increment and extended into the full 1.5mm thickness using a Teflon-coated plastic filling instrument and followed by light curing.

This micro gap splits the first composite increment diagonally into two equal segments. The segmented composite increment is then light cured. The created diagonal micro gap would enable, through its adhesion-free surfaces, each composite segment to undergo movement in outward direction towards the cavity walls rather than moving in vertical direction away from the pulpal floor, in contrast to what occurs in unsplit-composite increment after curing.

The outward movement is expected to exert a lateral pull on each composite segment in opposite direction away from the micro gap center and towards the bonded cavity walls. The outward movement of each composite segment in opposite direction is anticipated to greatly relieve the polymerization shrinkage stress and prevent debonding and internal micro gap formation within the adhesive layer before reaching its full bond strength potential. The diagonal micro gap is then filled with the same composite resin and light cured.(Figure 8).

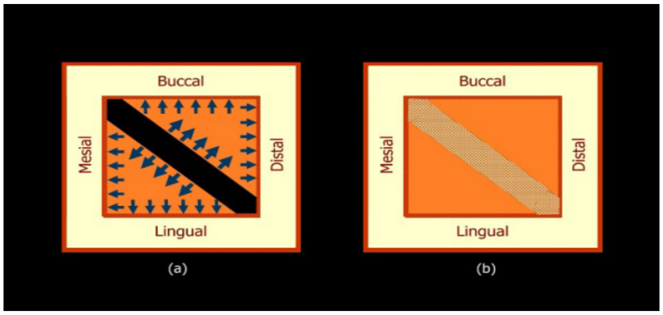

Figure 8: Sectional views showing the diagonally split first composite increment. (a) Upon polymerization, the diagonal micro gap enables movement of the 2 composite segments through the adhesion-free surfaces. Each composite segment undergoes movement in outward direction towards the cavity walls rather than movement in vertical direction away from the pulpal floor. (b) The diagonal micro gap is filled with the same composite resin and light cured.

Considering the small composite volume used for filling the diagonal micro gap, the generating shrinkage stress in the first composite increment is judged to be unable to cause deleterious effects on the adhesive interface at pulpal floor.

The diagonal splitting of the first thin composite resin increment acts as a shrinkage stress breaker during curing. The proposed biomimetic protocol protects the bonded interface at deep dentin on pulpal floor from debonding and internal micro gap formation, and thus prevents the occurrence of postoperative sensitivity and persistent pain. The restoration is completed in a similar way to that followed in the concept of "decoupling with time".

SUMMARY

The proposed protocol of "decoupling with split-increment" can be used as an alternative protocol for biomimetically restoring large occlusal composite resin restorations.

This protocol can redirect the shrinkage stresses generated at the pulpal floor, while the bond layer is still developing, and the hybrid layer is maturing. This prevents the incidence of debonding and internal micro gap formation beneath the restoration at the pulpal floor, subsequently preventing the occurrence of persistent postoperative sensitivity and pain.

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