

**The Effect of Resin Composite Inlay thickness on
Dentin Bond Strength and Nano-Leakage of a Dual-
Cure Resin Cement**

Thesis

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To my family

My Dear Mom & Dad

My lovely Sister

Thank you for everything, I am here now because of you

To My lovely wife and adorable baby boy

*You have been with me every step of the way with your love,
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Resin composite restorations applied by the direct technique were the most commonly used for placement of restorations in anterior and posterior teeth.¹ However, polymerization shrinkage was the major factor for long term restoration failure in such restorations.² In posterior restorations, gingival seat could be located in dentin, resulting in a large mass of resin composite needed to be light cured. In such situation, the polymerization shrinkage forces exceeded the adhesive joint bond strength forces leading to the formation of marginal gap regardless to the careful application technique.³ Indirect resin composite restorations were introduced to overcome the shrinkage problem of direct technique.⁴ Furthermore, indirect technique provide restorations with ideal occlusal anatomy and establishment of physiologic interproximal contact.⁵ Previous studies⁶⁻⁸ showed that with increased thickness of indirect restoration, light intensity reaching the resin cement layer decreased dramatically affecting the degree of conversion and bond strength between resin cement and tooth structure.

Dentin adhesive systems most commonly used with resin cements are simplified adhesives either in etch-and-rinse or self-etch modes. Simplified self-etch (SE) adhesives were found to be chemically incompatible with dual-cured (DC) resin cements.⁹ Recently, a new chemically-cured one-step two-component SE adhesive was introduced in the market under the name of “Tokuyama Universal Bond”. The manufacturer claimed that it overcomes the problem of incompatibility between SE adhesive and DC resin cements. The concept of the so-called Borate self-etch technology (BoSE), which is claimed to be better than the traditional chemical activator/initiator system (benzoyl peroxide/amine system). It displays a strong catalytic activity under low pH, due to the presence of borate and peroxide that acts as polymerization catalysts. (Tokuyama Universal Bond, Technical Scientific Product Profile, Tokuyama Dental Corp., Japan).

Resin-based cements are characterized by high mechanical properties and low water solubility. They are widely used in the cementation of fiber posts, ceramic veneers, all ceramic crowns and indirect composite or ceramic inlays/onlays.¹⁰ Dual-cured resin cements (DC) were developed to overcome the problems of limited curing depth in the light-cured resin cements as well as the prolonged setting time of the chemical cured one,⁶ as they offered extended working time and controlled polymerization.

In this regard, studying the effect of resin composite thickness bonded to dentin using a chemically-cured one-step SE adhesive/dual-cured resin cement could be of value.

I. Introduction to Resin composite

Modern dentistry develops along with patient's needs for high esthetics. Although restorations like gold and amalgam proved clinical success and longevity for many years. Nowadays, patients highly demand an esthetic restoration that look a lot like the natural tooth structure, not only for anterior teeth but also for posterior teeth as well.¹¹

Resin composite restorations were developed with many advantages including: esthetics, high resemblance to tooth structure in regard to transparency and shade, mechanical properties similar to dentin,¹² they bond well to hard tooth structure with the use of adhesive systems and are user friendly. One of the major drawbacks of resin composite restorations is the polymerization shrinkage which is reported to be 0.3-1.5% regarding the mean linear polymerization shrinkage, While 1.5-3.5% regarding the volumetric shrinkage.¹³ Other drawbacks as high occlusal wear and high thermal expansion which reaches 2–6 times higher than enamel and dentin.¹⁴

Composite resin materials consist of a matrix (organic polymer) and fillers (combination of inorganic particles) of different types. Some of these resinous materials are based on Bisphenol-A (BPA), which is used as a precursor of BPA glycidyl di-methacrylate (Bis-GMA) or BPA di-methacrylate (Bis-DMA). The BPA structure assembles a bulk, rigid chain that offers low susceptibility to biodegradation in addition to great rigidity and strength.¹⁵ Clinical, physical and mechanical properties of composite resins depend on the percentage of fillers in their volume, the particle size, load and matrix bonding of the filler. In fact, the more the size of the filler particle is, the less the wear resistance.¹⁶ However, these resins are less polish-able. Resin composites had gone through generations of traditional macro-filled composites, micro-filled composites, hybrid composites, micro-hybrid

composites and nano-composites. Nano-composites show high translucency, superior polish and polish retention together with maintaining physical properties and wear resistance equivalent to those of several hybrid composites.¹⁷

Conservative dentistry was introduced with a wide range of minimally invasive techniques for rehabilitation of posterior teeth. Resin composite restorations either performed with the direct or indirect technique, are from the best alternative non-metallic, esthetic restorative treatments.¹⁸

II. Direct versus indirect resin composite restorations

Traditionally, the cavity size to be restored determine the selection between direct and indirect techniques for resin composites in restoring defects of posterior teeth. Direct resin composite restorations are usually performed with small and medium sized cavities. While indirect restorations are highly indicated for large cavities, where the isthmus width surpasses two-thirds of the distance between buccal and lingual cusp tips.^{19,20} However, many clinicians are also using direct resin composite restorations in large cavities, due to the evidence that direct technique do not need invasive preparation and are performed in one visit only at relatively low cost, this made the clinical decision challenging.

Regarding direct restorations, resin composite material is directly placed into the prepared cavity and light cured. This technique allows maximum conservation of tooth structure, which fulfil the concept of minimally-invasive dentistry. Many challenges are accompanied with large posterior direct restorations, including exact reproduction of contours and occlusal anatomy/function that needs special clinical skills from the operator.²¹ In addition to the polymerization shrinkage problem,²² as the volume of resin

composite that will be cured became large, the polymerization shrinkage will be large as well, which will lead to generation of internal stresses in the resin composite material and the adhesive joint. However, if a strong adhesive joint is obtained by using a strong adhesive, polymerization shrinkage will mostly affect the tooth integrity by causing cuspal deflection and enamel cracking at the base of the cusp,²³ while if the internal stresses in the adhesive joint was greater than the tissue bond strength, the result will be detachment of the restoration and loss of the marginal seal.²⁴ This will lead to formation of a gap at the resin composite/dentin interface and micro-leakage.²⁵ The sequela of that will be manifested by postoperative hypersensitivity, while recurrent decay, marginal discoloration and fracturing of restorations and/or teeth will arise in the long-term.²⁶

Many trials were done to overcome the major problem of polymerization shrinkage in resin composites, in order to improve the adaptation of resin composite restorations in Class II cavities, either by changing the material composition, e.g. higher filler loading by adding more filler particles,²⁷ or by using different resins such as ormocers or siloranes with relatively high molecular weight.^{28,29} There were also clinical trials to decrease polymerization shrinkage by using different filling techniques for the prepared cavity as the oblique layering technique^{30,31} or by using glass ionomer restoration as a dentin replacement in the sandwich technique.³² Nowadays, Bulk filling materials available in the packable and flowable form gained attention as they achieved promising results regarding strength and stress reduction. It was shown that curing resin composite restorations with a high intensity light curing devices increases polymerization shrinkage.³³ Hence, it was recommended to use “soft start” or “ramp” curing techniques.³⁴ Unfortunately, these techniques had not eliminated polymerization shrinkage and its subsequent drawbacks completely.

Indirect resin composite restorations (Inlay/Onlay technique) was a promising method presented to overcome the problem of polymerization shrinkage of direct resin composite restorations as the shrinkage is confined to the thin layer of resin cement.³⁵ It was in 1987 when the first resin composite inlay system was introduced into the market.³ The desired form of the inlay could be performed by either direct/indirect, indirect or chair-side indirect technique. Based on a light-cured resin composite material, the direct/indirect technique (intraoral inlay) in which the restoration was formed directly in the inlay cavity after applying separating medium or Teflon tape adapted very well to the cavity as if using the tooth itself as a die. The inlay was initially light cured and then removed from the cavity, post-curing of the inlay was then performed in a heat and light oven at 110°C then cemented inside the cavity using resin composite cements. Indirect technique is performed by taking an impression of the prepared cavity and then fabrication of the inlay outside the patient's mouth (in the lab), while the chair-side indirect technique involves fabricating the inlay outside the patient's mouth (chair-side), using an impression of the prepared cavity and silicon die material then post-curing the inlay in the oven chair-side.

From the main advantages of the inlay technique was the post curing of the composite inlay, at a temperature above the lower glass transition temperature of the resin composite which led to improvement in the degree of conversion and also permitted the initial polymerization contraction and the subsequent post-cure stresses to happen before insertion. The relatively low stresses on the adhesive joint in the inlay technique led to an improvement in the bond and seal.³⁶ Furthermore, the inlay/onlay technique offered better physical and mechanical properties by post-curing the inlay/onlay with light or heat. In addition to, perfect occlusal anatomy, appropriate proximal contacts and wear compatibility with opposing tooth structure.^{37,38} From the drawbacks