Evaluation of Adaptation of Resin Composite Restorations Packed using Ultrasonic Vibration Techniques A Systematic Review

Sara Mohamed Hany*, Mai Mahmoud Yousry and Essam Abdel Hafiz Naguib
Faculty of Oral and Dental Medicine, Cairo University, Egypt; dr.sarahany@gmail.com, maiyousry@hotmail.com, essamnaguib50@gmail.com

Abstract

**Objectives:** The aim of this systematic review was to evaluate the effect of ultrasonic packing techniques using on the adaptation of resin composite materials. **Methods:** Two electronic databases were searched without limitations through May 2015. The terms Bulk packing, Sonic vibration, Dental marginal adaptation, Marginal assessment, Dental leakage, Void, and Composite resins were used. Screening through titles and abstracts was initially performed, and then articles that fulfilled the inclusion criteria were selected for a full-text assessment. **Findings:** The database search strategy retrieved fifty-nine potentially eligible studies. No duplicated studies were found. Titles and abstracts were screened and studies that fulfilled the inclusion criteria were selected for a full-text assessment. Finally, fifteen laboratory studies met the inclusion criteria and reference list for them was obtained. **Applications/Improvements:** Placement technique did not influence the adaptation of resin composite restorations. While the type of resin composite material influenced the extent of marginal adaptation. There is an interaction between the composition of the resin composite material and the application technique. The adaptation of new Sonic Fill system is promising and needs further investigations concerning its clinical longevity.

**Keywords:** Bulk Packing, Composite Resins, Dental Marginal Adaptation, Marginal Assessment, Sonic Vibration, Void

1. Introduction

Marginal integrity is crucial for the long-term survival of adhesively placed restorations. A major problem is polymerization shrinkage, which may initiate failure of the resin composite-tooth interface, resulting in interfacial gaps. Restoration placement techniques, although controversial, are widely regarded as influential in the modification of shrinkage stresses. Incremental placement of light-activated resin composite has been recommended to decrease overall contraction by reducing the bulk of the material cured at one time. It was also assumed that the thixotropic effects due to the application of ultrasound would reduce the development of stress by increasing material flow, thus enhancing wetting properties of composite resin materials leading to improved marginal quality. 80 box-only Class II cavities were prepared mesially and distally in 40 extracted human molars using four different oscillating diamond coated instruments: (A.

Tight marginal seal still has to be the primary goal for the clinicians, because gap formation with restorative materials cannot be counteracted once happened. Although remarkable improvements have been conducted in the technology of resin composite materials, failures are still reported. Poor adaptation along the restoration margins have been established as one of the most common problems of posterior resin composite restorations. "Ormocer" materials have been introduced over the past few years. The purpose of this study was to evaluate the marginal and internal adaptation of two ormo-cer restorative systems (Admira, Voco and Definite, Degussa.

The relatively high viscosity and the presence of voids in resin composite materials result in insufficient adaptation to the dental substrate which will probably affect the
clinical performance of the material. Application of resin composite using ultrasonic vibration technique decreases the initial viscosity of the material, thus promoting adequate wetting and adaptation of the densely filled resin composite onto the dental substrate.

Some manufacturers of resin composites have recommended placing the restorative material in a single increment with 5 mm of thickness as they did not find a statistically significant difference between placing the material in increments or in bulk.

Oscillation energy has been proposed in as a new method to pack resin composite. The principle of this technique assumes that vibration lowers the viscosity of the resin, allowing the material to flow and easily adapt to the cavity walls in a similar way as a flowable resin composite.

SonicFill was introduced in the dental market and it combines the properties of a flowable resin composite with those of a universal resin composite. Oscillation energy temporarily increases the flowability of the resin composite to achieve precise filling of cavities, leads to rapid placement through a single increment up to 5mm due to reduced polymerization shrinkage, and thereby reduce the working time.

2. Materials and Methods

The PRISMA (Preferred Reporting Items for Systematic Review) statement was used as a reporting template as much as possible (Figure 1).

2.1 Data Collection

A systematic search of electronic databases was conducted using PubMed and Google scholar up to May 2015 without limitations.

2.2 Criteria for Selection of Studies

Screening was performed to all the titles according to these inclusion criteria:

- In-vitro studies.
- Using only human teeth.
- Application of vibration during resin composite application.

The following exclusion criteria were applied in addition

- Clinical evaluations.
• Performing tests other than adaptation (e.g., bond strength, hardness, cuspal deflection, depth of cure).
• Using language other than English.
• Using bovine teeth.
• Articles older than 2005.

A search with relevant title/abstract was conducted at the beginning (primary screening) followed by assessment of full articles (secondary screening) in order to select the included studies. An attempt was made to retrieve full articles for all potentially relevant abstracts that were already published, and those abstracts that were published with insufficient details were reported as N/A in the methodology table (Table 1).

2.3 Data Extraction

The fifteen studies were analyzed with regard to type of teeth, sample size, resin composite materials, cavity classifications, placement technique, packing technique, method of adaptation assessment, adaptation assessment site and age. The fifteen selected studies were compared to the study methodology of the selected studies.

2.4 Methodological Data among the Selected Studies

A customized systematic evaluation protocol (Table 1) was created to compare the study methodology of the selected studies.

3. Results

Table 2 represents the results of the fifteen individual laboratory studies included in this systematic review.

3.1 Risk of Bias across Studies

Difference in the test parameters from one study to the other made it unable to perform meta-analysis.

4. Discussion

Manual and ultrasonic vibrational packing techniques were investigated in this systematic review in order to detect if the placement technique has an effect on the adaptation of resin composite restorations or not.

When it comes to the application method; one study used the compothixo vibration condensation instrument which applies vibration after placement, four studies used the ultrasonic vibrational tips, and the rest of the studies used SonicFill system which applies vibration during the placement of the material.

With the Compothixo the vibration seemed to make the material more adherent to the instrument and more difficult to apply leading to formation of a hiatus at the interface between restoration and cavity walls.

Studies about SonicFill reported the benefits of sonic activation; low contraction stress, increase marginal integrity, reduce bulk fracture and no voids.

All studies reported the results of the marginal adaptation and microleakage whether in size of gap, dye penetration scoring or by describing the interface and all were well clarified methods for adaptation evaluation.

This systematic review denotes that despite the expected benefits of the ultrasonic packing techniques with highly-filled resin composite materials, yet ultrasonic packing was not significantly advantageous over manual packing technique, due to the occurrence of polymerization shrinkage (1.6-1.8%) with almost the same degree with all tested materials.

A study found that ultrasonic packing technique resulted in better but not statistically significant different interfacial adaptation values compared to application without ultrasonics of condensable composites, and another study found that SonicFill and Filtek Supreme composites did not differ regarding results of adaptation.

SonicFill placed in a single bulk increment showed in a study equal marginal integrity compared to other manually placed bulk fill and conventional materials. While in another study no significant difference was found between SonicFill bulk placed material and conventional incrementally packed material with regards to marginal imperfections, openings and cracks.

On the contrary, an article article reported that the most favourable gap results were obtained when the application of the bulk-fill material took place using the activating sonic handpiece.

Among the fifteen selected studies, six compared the effect of bulk and incremental placement techniques of resin composite materials on the adaptation of resin composite restorations, five studies used only bulk placement...
| Author, Year | Type of teeth | Sample no. | Material | Cavity | Microscope | Placement technique | Packing technique | Gap Measurement site | Aging |
|--------------|---------------|------------|----------|--------|------------|---------------------|------------------|---------------------|-------|
| Schmidlin et al, in 2005 | Tetric, and Tetric Ceram | Human molars | 48 | ok | Ok | Ok | Manual ultrasound | N/A |
| Hassan & Ghulman, in 2006 | Human premolars | 20 | Ok | Ok | Ok | Optic | N/A |
| Schmidlin et al, in 2007 | Human molars | 80 | Ok | OM or OD | Ok | Ok | N/A |
| Iovan et al, in 2011 | Human molars | 20 | ok | Ok | Ok | Ok | 40N 1.7Hz, 12,0000 thermal cycles (5-50 ºC) |
| Eunice et al, in 2012 | Human molars | 30 | ok | Ok | Ok | 3 mm | 500 Thermal cycles (5-55ºC) |
| Begino et al, in 2012 | Human molars | 25 | ok | Ok | 5 mm | ok | 100 thermal cycles (5-55 ºC) |
| Frankenberger, in 2012 | Human molars | 64 | Ok | MOD | Ok | 5 mm | 100,000× 50N mechanical cycles, 2,500 thermal cycles (5-55 ºC) |
| Munoz-Viveros et al, in 2012 | Human molars | 15 | ok | Ok | Ok | Ok | 1000 thermal cycles (5-55ºC) |
Campos, et al. 2014 impressions were made using a polyvinyl siloxane and epoxy resin replicas were obtained. Thermo-mechanical stressing was carried out 24 h after the restorative procedure. All specimens were submitted to 240,000 occlusal loading and simultaneous 600 thermal cycles in water at 5°C and 50°C. After loading, a new set of epoxy resin replicas was obtained. Scanning electron microscopy was carried out at 200X magnification. Results for the marginal adaptation were expressed as percentages of continuity relative to the exposed interface and analyzed by ANOVA and Duncan post hoc test (p < 0.05).

| Study               | Type      | Human | Occlusal Loading | Thermal Cycles | Marginal Adaptation |
|---------------------|-----------|-------|------------------|----------------|---------------------|
| Furness et al, 2014 | Molars    | 40    | Ok               | Ok             | Ok                  |
| Yaroub & Hameed, 2014 | Molars    | 36    | Ok               | Ok             | Ok                  |
| Agrwal et al, 2015  | Premolars | 80    | Ok               | Ok             | Ok                  |
| Benetti et al, 2016 | Molars    | NA    | Ok               | Ok             | Ok                  |
| Kim et al, 2017     | Molars    | N/A   | Ok               | Ok             | Ok                  |
| Orlowski et al, 2018 | Molars    | 30    | Ok               | Ok             | Ok                  |
| Author, Year | Measurement of marginal gaps |
|--------------|-----------------------------|
| Schmidlin7 Tetric, and Tetric Ceram et al, in 2005 | 1) packable  
a- manual= 120-131 µm  
b- ultrasonic= 56-94 µm  
2) microhybrid  
a- manual= 84-115µm  
b- ultrasonic= 63-99µm  
3) flowable  
a- manual= 47-77µm  
b- ultrasonic= 49-74µm |
| Hassan & Ghulman, in 20068 | Manual 14.47±6.69  
Ultra-sonic 10.97±5.07 |
| Schmidlin et al, in 2007 | 80 box-only Class II cavities were prepared mesially and distally in 40 extracted human molars using four different oscillating diamond coated instruments: (A  
% of continuous margin:  
- proximally:  
1) without ultrasound:  
a) before loading 86-93%  
b) after loading 42-76%  
2) with ultrasound:  
a) before loading 82-94%  
b) after loading 68-85%  
- cervically:  
1) without ultrasound:  
a) before loading 72-89%  
b) after loading 40-77%  
2) with ultrasound:  
a) before loading 73-93%  
b) after loading 36-86% |
| Iovanet al, in 20115 | manual packing: Inconsistent (areas of adequate adaptation alternating with areas of poor adaptation)  
-vibrational packing: appropriate adaptation to cavity walls with very small irregularities |
| Eunice et al, in 20126 | SonicFill = 0.08  
Nanocomposite = 0.07 |
| Begino et al. in 20139 | Occlusal = 0.1-2.3 mm  
Cervical = 0-0.7 mm |
| Frankenberger, in 201310 | Gap free margin (%):  
Enamel = 100%  
Enamel TML= 84%  
Dentin= 98%  
Dentin TML = 60% |
| Munoz-Viveros11 et al, in 2013 | Sonic Fill had the least microleakage, it is void free, and equivalent marginal adaptation to incrementally applied materials |
Impressions were made using a polyvinyl siloxane and epoxy resin replicas were obtained. Thermo-mechanical stressing was carried out 24 h after the restorative procedure. All specimens were submitted to 240,000 occlusal loading and simultaneous 600 thermal cycles in water at 5°C and 50°C. After loading, a new set of epoxy resin replicas was obtained. Scanning electron microscopy was carried out at 200X magnification. Results for the marginal adaptation were expressed as percentages of continuity relative to the exposed interface and analyzed by ANOVA and Duncan post hoc test (p < 0.05).

| Reference                     | Findings                                                                                       |
|-------------------------------|------------------------------------------------------------------------------------------------|
| Campos, et al 2014            | No difference in marginal adaptation between bulk-fill material and standard composite        |
| Furness et al, in 2014        | Sonic-Fill Bulk = 45% gap free margins                                                        |
|                               | Sonic-Fill Incremental = 58% gap free margins                                                |
| Yaroub & Hameed, in 2014      | Sonic fill™ bulk fill composite showed significantly lesser marginal gaps width at occlusal, proximal and gingival composite/enamel interface regions in comparison with packable composite using horizontal incremental technique. |
| Agrwal et al, in 2015         | Results of cervical enamel gap:                                                               |
|                               | Gr. I - Sonic Fill = 94.420±6.594                                                             |
|                               | Gr. II – SDR = 93.380±7.010                                                                   |
|                               | Gr. III – Tetric N Ceram Bulk Fill = 92.130±5.852                                              |
|                               | Gr. IV – Tetric N Flo + Tetric N Ceram = 93.530±7.550                                          |
| Benetti et al, in 2015        | Bulk-fill materials exhibited a gap formation similar to that of the conventional resin composite |
| Kim et al, in 2015            | The flowable composites exhibited higher shrinkage and lower modulus than the packable composites |
| Orlowski et al, in 2015       | 90% of restorations of SonicFill system scored 0 = no dye penetration                         |

1Universal composite (hybrid)  
2Sonicfill  
3Nanocomposite  
4Packable  
5Flowable  
6Microfilled  
7Comp-o-thixo  
8Immersion in sodium pertechnetate for 3 hrs then radioactivity detected by gamma camera  
9Digital Microscope  
10Shrinkage-stress measuring instrument, Acoustic emission analysis

| Method          |
|-----------------|
| Immersion in sodium pertechnetate for 3 hrs then radioactivity detected by gamma camera |
| Digital Microscope |
| Shrinkage-stress measuring instrument, Acoustic emission analysis |
technique and four studies applied only incrementally placed materials.

These studies that compared the two placement techniques revealed no significant difference between the placement techniques regarding the adaptation of resin composite restorations.

This systematic review did not evaluate the effect of the resin composite material itself on the adaptation (the flow characteristics and the composition), but different between techniques was highlighted by manual packing and concealed by the ultrasonic packing techniques. This result could be explained by the difference in material properties as well as incremental versus bulk packing of the materials. With advances in new bulk-fill composite materials, shrinkage stresses at the margins are expected to be less, as a result of the ability of unpolymerized composite at the depth of the restoration to deform and “feed” the resulting stress development from the strain of composite curing at shallower depths. Thus, despite reduced volume of composite, higher stress development is expected to have occurred in the 2-mm thick incremental packing technique, with higher percentages of gap and less intact margins due to the absence of a deep reservoir of uncured composite from which polymerization stresses of the upper composite segment could be relieved.

As regarding flow of the material during setting; chemically activated materials had the upper hand as they polymerize more slowly and this give them greater capacity to flow during their longer gel stage so they generate lower stresses on the adhesive bond. During light curing, resin matrix is converted to a polymer network leading to closer packing and shrinkage. Shrinkage is compensated for after that by viscous flow until resin reaches its gel point. Viscous flow is reduced shortly after commencing light curing and stress is transferred to the cavity walls. After that shrinkage is largely counteracted by adherence and plastic flow. On the other hand the composition affects the light dispersion which is very critical especially in bulk placed materials; (increase micro-particles, increase light dispersion and reduced polymerization) in deep areas\textsuperscript{80} box-only Class II cavities were prepared mesially and distally in 40 extracted human molars using four different oscillating diamond coated instruments: (A.

Gap reflects interaction between resin composite material (polymerization shrinkage, material flow during setting, composition), placement technique and contraction stress\textsuperscript{20}, so we need a material and a technique that can prevent contraction stress and both are still not present since the long term behavior of newly introduced SonicFill system is still unknown.

5. Conclusions
- Placement technique did not influence the adaptation of resin composite restorations.
- Type of resin composite material influenced the extent of adaptation.
- There is an interaction between the composition of the resin composite material and the application technique.
- The adaptation of new SonicFill system is promising and needs further investigations concerning its clinical longevity.

5.1 Recommendations
- Recent studies and clinical trials that evaluate different application techniques and bulkfill materials should be periodically reviewed\textsuperscript{21–23}.
- Data about different adaptation testing procedures should also be collected and reviewed whenever possible\textsuperscript{24}.

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