EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 22, No. 4, October 2025, pp. 10 - 19 **ISSN 2090 - 5882**
(Received May 15. 2025, Accepted in final form September 01. 2025) **jest.journals.ekb.eg**

ABRASIVE WEAR RESISTANCE OF COMPOSITE RESIN

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ABSTRACT
Composite resins are extensively used in direct dental restorations. The performance of composite resins is influenced by the procedure of application and light curing mode. The application of the composite resin may be in bulk-fill and incremental layering that differ polymerization depth and mechanical properties. Besides, light curing methods such as continuous and pulsed ones affect the degree of polymerization and durability. The present study investigates the wear resistance and friction coefficient of resin composite restorations using bulk-fill and incremental layering by continuous and pulsed light curing modes under controlled laboratory conditions. Accelerated wear tests were carried using pin on disc test rig at different loads to simulate oral masticatory forces.

The results showed that utilizing the pulsed light curing mode displayed lower fiction and wear compared to continuous curing. Applying composite resin in two and three layers for continuous curing, showed relatively lower wear rather than bulk-fill. Besides, incremental layering enhances the degree of polymerization, while bulk-fill of pulsed curing showed the lowest wear. Finally, it is recommended to consider both the impact of curing mode and layering technique together, rather than relying on one factor alone, to get optimal long duration performance of composite restorations.

KEYWORDS
Abrasive wear, friction, composite resin, bulk-fill, layers, continuous, pulsed light curing modes.

INTRODUCTION
It was revealed that high-viscosity bulk-fill composite resin has higher microhardness that enables it to be applied in a single layer without capping, while the low-viscosity bulk-fill composite should be covered by a bulk-fill or conventional composite at the top surface, [1]. Composite resin is widely used to restore teeth, [2 - 4]. It was observed that fatigue is initiated from internal cracks during the large restorations, [5]. Thus, to have higher strength, composite resin requires appropriate photoactivation by radiant exposure of light-curing unit, [6, 7]. Processing of conventional composite

resin needs a dry surface, etching, priming and bonding with incremental thickness of 2 mm, [8, 9]. The addition of filling materials in the resin influences shrinkage polymerization shrinkage, [10], where the elastic modulus increases causing significant shrinking and enamel cracking, [11]. It was found that composite shrinkage was not influenced by the different light curing modes, [12]. Besides, the closer the tip of the curing light to the composite surface, the less the polymerization shrinkage. It is essential to increase the light curing time to polymerize resin composite in the deep cavities to increase both the hardness and compressive strength of composite resin, [13].

Adhesive restoration depends mainly on dental resin composites, [14]. The drawback of the polymerization of the resin matrix is the volumetric shrinkage, [15], where the decrease in the volume around monomers leads to macroscopic shrinkage of the material that induces surface stress. Volumetric shrinkage is related to polymerization stress, it influences the elastic modulus, [16, 17]. The stress causes microleakage, [18 - 22]. It was revealed that pre-heating of composite resins modified the material properties by increasing the monomer mobility and polymerization rate, [23 - 25]. Increasing the time of light exposure, [26, 27], increases the polymerization stress.

The perfect polymerization of resin composites is necessary to get a long durating dental restoration of good mechanical properties. Polymerization is a process where monomers are linked together to form chains of molecules called polymers. The groups of monomers possess carbon-carbon double bonds (C=C) of two pairs of electrons sharing two carbon atoms. Then other atoms can be linked to the carbon atoms. The polymerization includes activation, initiation, propagation and termination reactions, [28 - 34]. In activation the free radicals are released to initiate polymerization. Then free radicals open the double bond to be linked to other monomers forming polymer chains. In the propagation, new monomers are added to the polymer chain. When the number of monomers decreased the reaction ends. This process is called termination phase. The molecular weight of the polymer is the sum of the molecular weights of the all monomers linked together. As the number of monomers in the chain increases, the degree of polymerization increases, [35 - 37]. Good polymerization is essential for a good composite restoration.

The process of light polymerization is called photopolymerization. Light curing polymerization is used in the present work, [38]. The advantage of polymerization with light curing is the control of the working time. The major factors affecting polymerization is the thickness of the composite resin, where thickness of 2 mm is recommended. As the thickness of composite resin increased, the light applied loses its intensity at the bottom surface drastically affecting the mechanical properties [39 - 41]. Besides, composite resin should have a certain content of initiator that responds to the light curing.

The objectives of the present study are to compare the wear resistance and friction coefficient of resin composite restorations using bulk-fill and incremental layering by continuous and pulsed light curing modes.

EXPERIMENTAL

The composite resin used in the study was RubyFill Nano (RubyDent, Germany). It contains nano-sized filler particles to enhance its mechanical properties and wear resistance. Light curing of the tested specimens was performed using the 3D Star LED Light Curing Device using continuous and pulsed light curing modes. To simulate the accelerated abrasive wear, P1000-grade silicon carbide abrasive paper was adhered to the rotating disc of the wear tester representing the counter surface. Wear tests were performed using a pin on disc test rig, Fig. 1, at dry sliding condition. Wear was measured by the weight loss after test using electronic balance of ± 1.0 mg.

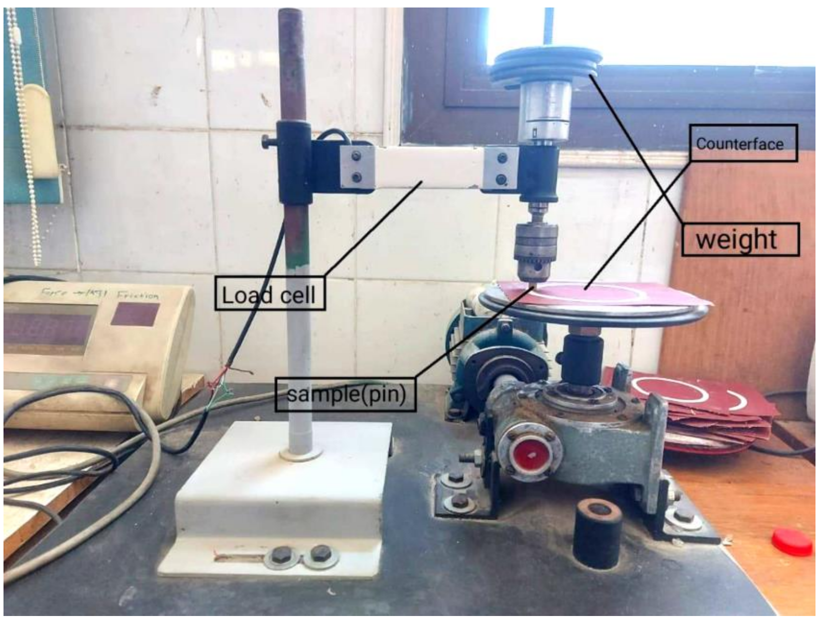

Fig. 1 Pin on disc test rig.

The resin composite specimens were prepared by continuous and pulsed curing modes. The tested specimens were bulk-fill, two layers, three layers and four layers. Each specimen was molded in a cylindrical pin with a height of approximately 13.5 mm and a diameter of 6 mm. For bulk-fill specimens, the entire volume was filled in a single increment. In layered specimens, the composite was applied incrementally, with either two, three and four layers. For bulk-fill specimens, curing was performed for 60 seconds from the top surface, while for layered specimens, every layer was cured for 60 seconds immediately after filling. The test duration was 30 seconds under 8, 10 and 12 N applied load at 2.0 m/s sliding velocity. Friction coefficient (μ) was determined by the ratio between friction force and applied load. Friction force was continuously recorded using load cell assembled in the loading lever.

RESULTS AND DISCUSSION

The friction coefficient displayed by the tested specimens revealed a slight decrease with increasing the applied load, Fig. 2. Two and three layers treated by continuous light showed slight friction decrease. While bulk-fill experienced the highest friction coefficient up to 1.0 at 8 N load. Specimens subjected to pulsed curing light exhibited relatively lower friction values than that observed for continuous curing mode, Fig. 3. The three layers pulsed specimens showed the lowest friction values of 0.78, 0.73 and 0.7 at 8, 10 and 12 N load respectively. That observation underscores the ability of pulsed curing to minimize friction values. Using two or three layers showed significantly lower friction than bulk-fill specimens, particularly when combined with pulsed curing. No further decrease was observed for the four layers specimens. It can be concluded that both curing protocol and application procedure significantly influence the frictional properties of composite restorations.

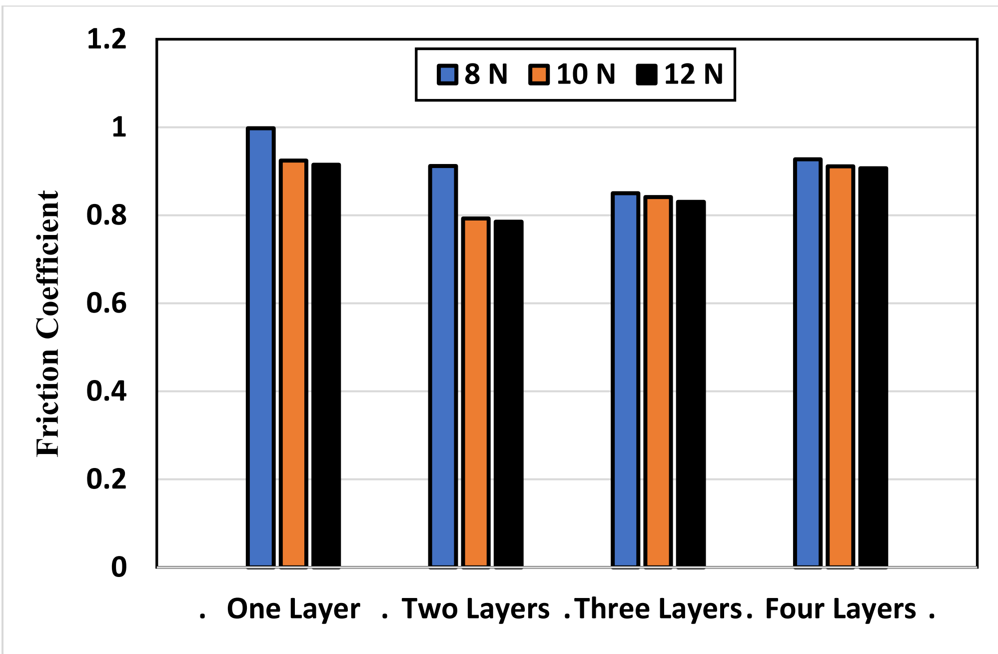

Fig. 2 Friction coefficient displayed by the sliding of test specimen prepared by continuous curing light.

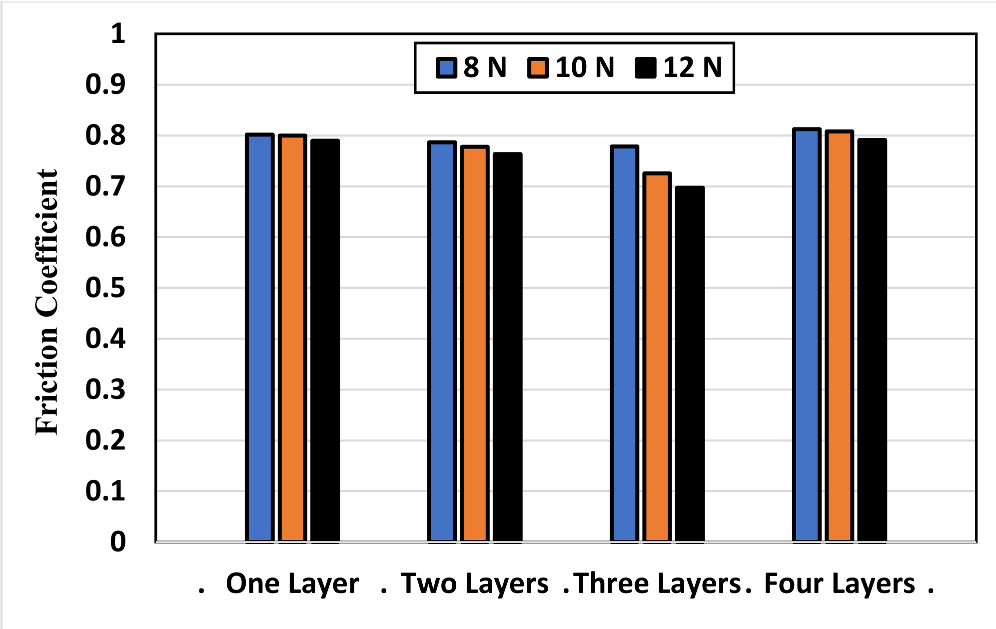

Fig. 3 Friction coefficient displayed by the sliding of test specimen prepared by pulsed curing light.

The wear increased as the applied load increased. Specimens treated by continuous curing showed that specimens of two, three and four layers displayed lower wear values than that observed for bulk-fill specimens, Fig. 4. It seems that layering the composite resin enhanced the degree of polymerization, increased the crystallinity and reduced material degradation. Specimens cured by pulsed mode exhibited lower wear values, Fig. 5. The bulk-fill pulsed specimens showed the lowest wear compared to the multilayer specimens. That behavior may result from that layering introduced weak interfaces or structural inconsistencies. Specimens contained two and three layers under continuous mode showed good resistance to wear. This suggests that layering, combined with pulsed curing is not recommended. Increasing the number of layers beyond three did not lead to additional improvements. The four layers specimens, in pulsed mode, did not perform better than the two and three layers.

It seems that pulsed curing increased the degree of polymerization where the time consumed in curing was longer facilitating the free radicals to open the double bond to be linked to other monomers forming polymer chains, adding new monomers to the polymer chain, increasing the molecular and enhancing the degree of polymerization.

Figure 6 illustrates the hardness of test specimens prepared by continuous and pulsed curing light, where the pulsed cured test specimens showed relatively higher values than that measured for the continuous cured test specimens. This observation confirms the enhanced wear resistance due the hardness increase.

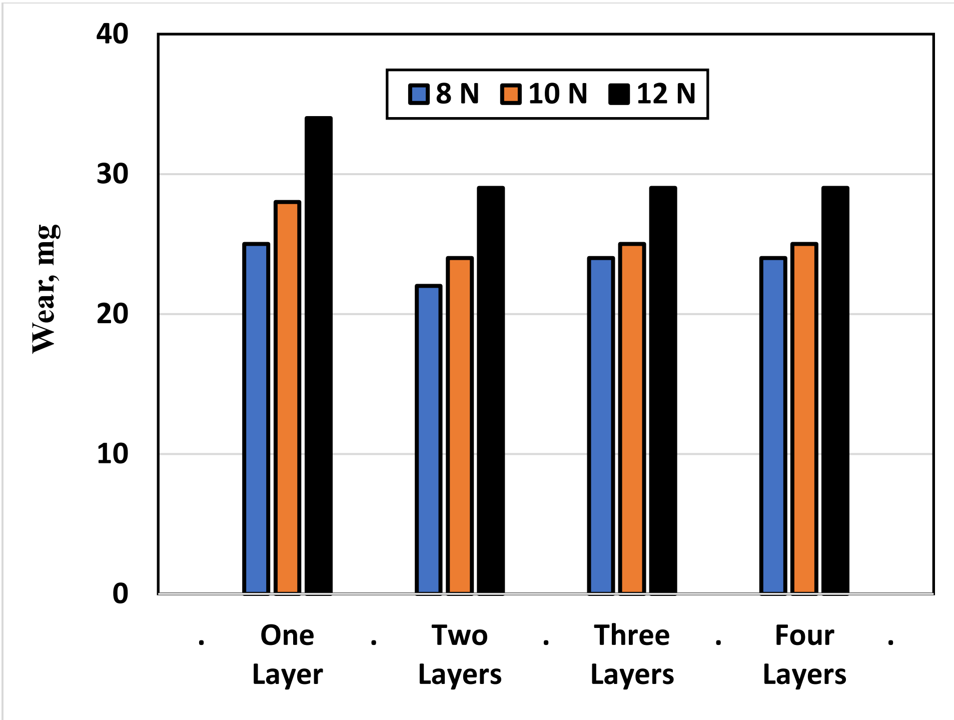

Fig. 4 Wear displayed by the sliding of test specimen prepared by continuous curing light.

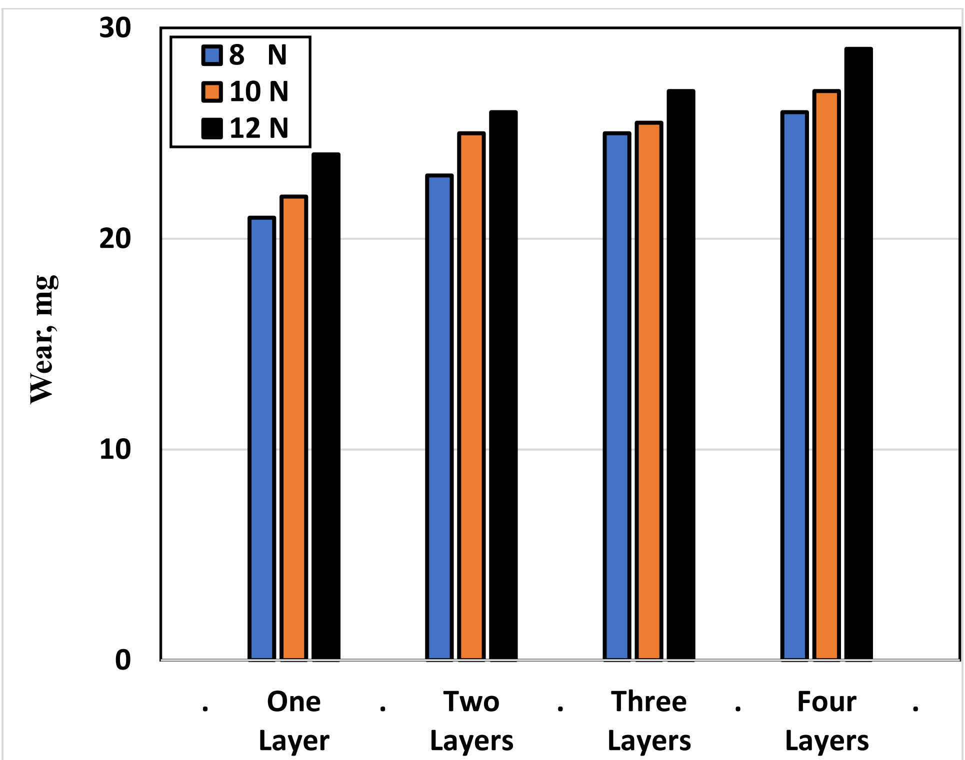

Fig. 5 Wear displayed by the sliding of test specimen prepared by pulsed curing light.

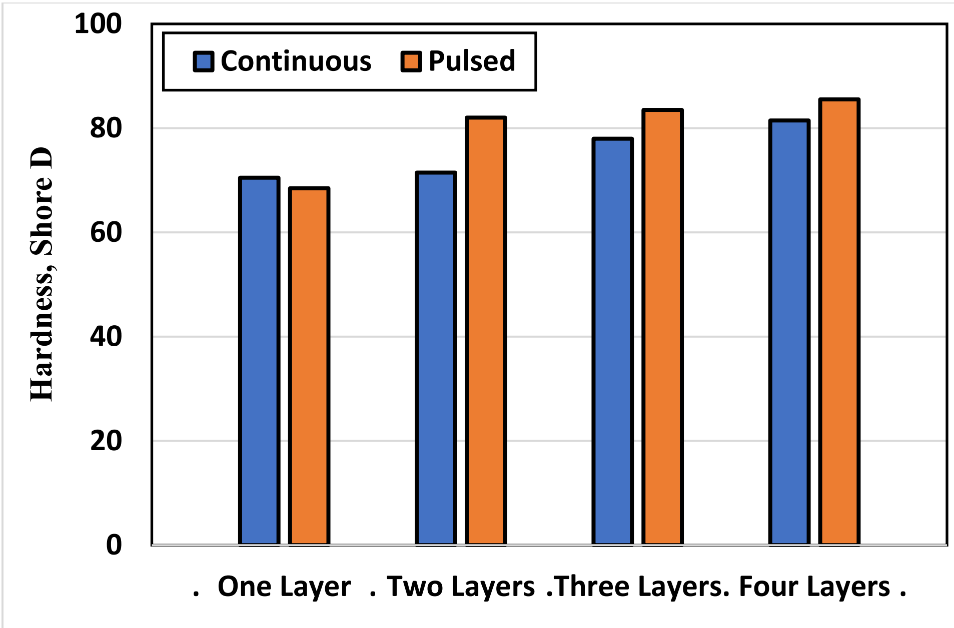

Fig. 6 Hardness of test specimens prepared by continuous and pulsed curing light.

The experimental results indicates that pulsed curing enhances wear resistance. Besides, incremental layering improves tribological and mechanical properties, increases polymerization depth and decreases internal stress. Application of increments of 2 mm layer leads to enhanced mechanical properties. The superior performance observed in bulk-fill, two and three layers for pulsed specimens, while continuous cured specimens showed lower wear for specimens of two and three layers.

It is observed that continuously cured bulk-fill composites did not have enough resistance to wear, while pulsed cured specimens could enhance restoration. In addition to that, the wear test was conducted under relatively higher sliding velocity, where the counter surface was P1000-grit silicon carbide abrasive paper to give specific information on the tribological properties of the tested specimens. This testing method does not fully simulate the actual condition but serve as accelerated wear testing that serves for comparative performance but not fully describes the long-term clinical performance of restorative materials. Besides, removal of abrasive particles can affect the wear and friction measurements. The surface of the abrasive paper was inspected and replaced every 10 seconds. Finally, the present study provides controlled comparison of the clinical variables offering specific information about the friction and wear behavior of composites under varying curing and placement conditions.

CONCLUSIONS

1. Application of the pulsed light curing protocols showed reduced fiction and wear compared to continuous curing.
2. For continuous curing, applying composite resin in two and three layers showed relatively lower wear rather than bulk-fill.

3. Incremental layering improves stress distribution and increases the degree of polymerization.
4. Bulk-fill with pulsed curing displayed the lowest wear.
5. It is recommended to advise the clinicians to consider the impact of curing mode and layering technique together, rather than relying on one factor alone, to achieve optimal long-term performance of composite restorations.

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