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TRIBOLOGICAL BEHAVIOR OF COMPOSITE RESIN

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ABSTRACT
The present work investigates the friction coefficient, wear resistance and voltage generated from the sliding of resin composite made by bulk-fill and incremental layering by continuous and pulsed light curing modes on abrasive paper as the counter surface to compare the performance of the tested specimens. The experiments have been carried out at reciprocating motion of low velocity to simulate the oral masticatory condition.

It was found that test specimens prepared by continuous curing light of two layers showed the highest friction values at dry sliding. Friction coefficient decreased by increasing applied load. At water wet sliding, test specimens of layers displayed higher friction values than bulk fill ones. In addition, voltage increased as the applied load increased, where specimens of bulk fill displayed the highest voltage, while specimens of layers showed the lowest voltage values. Water wet sliding decreased the voltage due to the presence of water. Specimens prepared by pulsed curing light showed lower friction than that determined for continuously cured ones. At water wet sliding, pulsed light cured test specimens displayed higher friction than that show in dry sliding. Specimens treated by pulsed light showed higher voltage values that that observed for that treated by continuous light curing. Finally, water wet sliding caused higher wear values that dry sliding for continuously light cured specimens, while the lowest wear was shown for three layers specimens. Besides, bulk fill specimens displayed the lowest wear in water wet sliding.

KEYWORDS
Friction coefficient, abrasive wear, composite resin, bulk-fill, layers, continuous, pulsed light curing modes.

INTRODUCTION
Recently, it was found that application of the pulsed light curing mode showed lower fiction and wear compared to continuous curing, [1]. Besides, composites consisting of two and three layers continuously cured displayed lower wear rather than bulk fill. It was observed that incremental layering improved the degree of polymerization. In other study, it was revealed that bulk fill composite resins have higher microhardness.

Therefore, bulk fill could be applied in a single layer without capping, [2]. Composite resin is extensively applied to restore teeth, [3 - 5]. It was approved that fatigue can be initiated from internal cracks inside the restorations, [6]. Thus, to get higher strength, composite resin needs exposure of light-curing unit, [7, 8]. Processing of composite resin requires incremental thickness of 2 mm, [9, 10]. The shrinkage polymerization shrinkage can be mitigated by filling materials in the resin, [11]. The increase of elastic modulus causes significant shrinking and enamel cracking, [12]. It was found that composite shrinkage was not affected by the light curing modes, [13]. As the tip of the curing light gets closer to the composite surface, the less the polymerization shrinkage. It is necessary to increase the light curing time to increase the degree of polymerization of the composite resin in the deep cavities to increase the hardness and compressive strength, [14].

The disadvantage of the polymerization of the resin matrix is the volumetric shrinkage, [15, 16]. Volumetric shrinkage induced polymerization stress and influenced the elastic modulus, [17 - 23]. It was revealed that preheating of composite resins enhanced the mechanical properties by increasing the monomer mobility and the degree of polymerization, [24 - 26]. Besides, increasing the time of light exposure, [27, 28], increases the hardness of the composite resin.

It is known that perfect polymerization of resin composites is essential to get a long last dental restoration of better mechanical properties. Polymerization process contains activation, [29 - 35], where the free radicals initiate polymerization. Then, free radicals are linked to the other monomers to form polymer chains. Increasing the number of monomers in the chain increases the degree of polymerization, [36 - 39]. Good polymerization is essential for a good composite restoration.

Polymerization with light curing controls of the working time, [40]. It is affected by the thickness of the composite resin. The thickness of 2.0 mm is recommended. The increase of the thickness reduces the intensity of the light at the bottom surface and drastically affects the mechanical properties, [41 - 43].

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

EXPERIMENTAL

The resin composite used in the study was treated by light curing using the 3D Star LED device utilizing continuous and pulsed light curing modes. The counter surface was P1000-grade abrasive paper of silicon carbide adhered to the reciprocating table of the wear tester. The sliding velocity was approximately 0.1 m/s to simulate the massification process, Fig. 1. An electronic balance of ± 0.1 mg accuracy was used to evaluate the wear by weight loss after test.

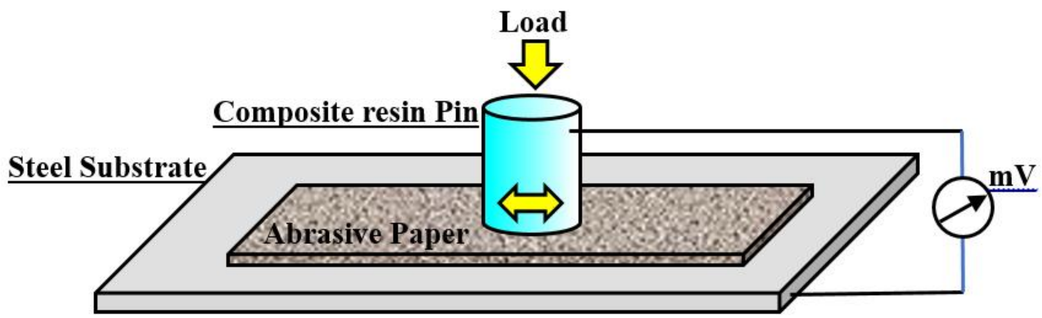

Fig. Details of the wear tester.

The tested specimens were prepared as bulk-fill, two layers, three layers and four layers treated by continuous and pulsed curing modes. The test specimen was in form of cylindrical pin of approximately 12 mm and 6 mm diameter. The bulk fill specimens, the specimen was molded in a single increment, while in layered specimens, composite with two, three and four layers was applied incrementally. Light curing was applied for 60 seconds on the top surface for bulk fill specimens, while every layer was cured for 60 seconds after filling for layered specimens. The test specimens were loaded on the counter surface at 6.0 N load. They slid at 0.1 m/s and stroke of 40 mm. The total sliding was 2.0 m. Friction coefficient (μ) was evaluated by the ratio between friction force and applied load where friction force was measured by load cell. The composite resin pin was assembled in steel representing one terminal while the steel substrate represented the second terminal for voltage measurement. The voltage generated from the sliding of composite resin on abrasive paper was measured by digital voltmeter of ± 0.1 mV accuracy.

RESULTS AND DISCUSSION

The friction behavior of test specimen prepared by continuous curing light is illustrated in Fig. 2. Test specimens prepared by two layers, slid on the abrasive paper, displayed the highest friction values. Generally, friction coefficient gradually decreased by increasing applied load due to the heat generated during sliding at higher loads. The heat rise formed a polymeric layer of low shear strength on the sliding surface that was responsible for reducing the friction coefficient. At water wet sliding, test specimens prepared in layers showed higher friction values than the bulk fill ones, Fig. 3. The values of friction coefficient were higher than that observed in dry sliding. It seems that water removed the worn particles adhered to the abrasive paper facilitating the abrasion process.

The voltage generated from the dry sliding of the test specimens continuously light cured is shown in Fig. 4. Bulk fill specimens displayed the highest voltage, while specimens of two, three and four layers showed relatively lower values. Voltage values increased with increasing the applied load due to the increase of the contact area, where the highest value reached 150 mV at 10 N load. At water wet sliding, Fig. 5, voltage values drastically decreased due to the presence of water that conducted the voltage between the two sliding surfaces. The highest voltage value did not exceed 12 mV.

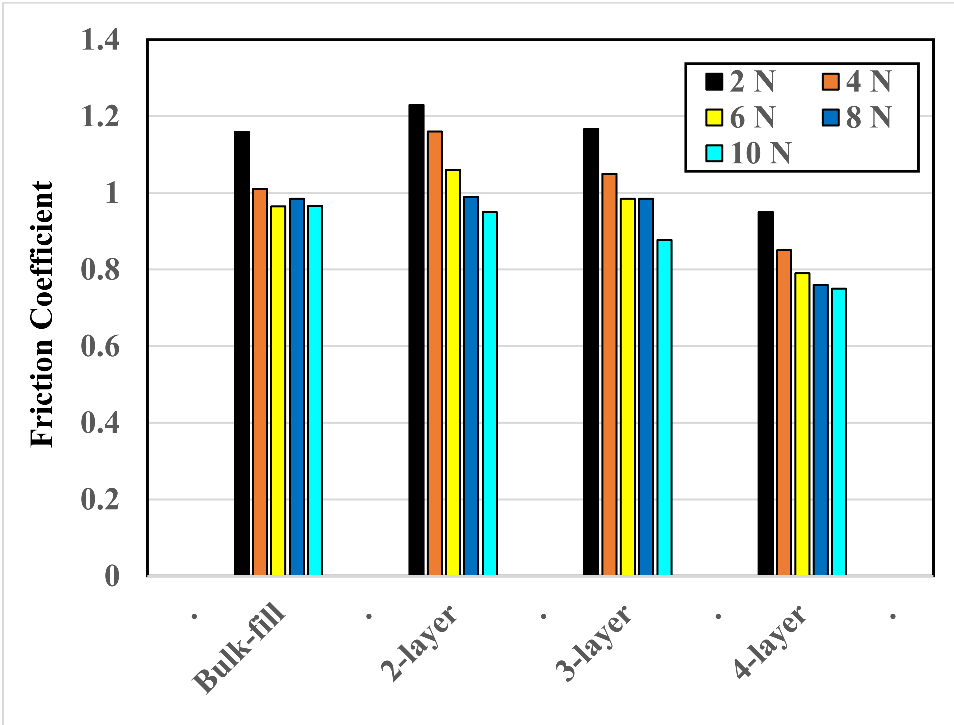

Fig. 2 Friction coefficient displayed by the dry sliding of test specimen prepared by continuous curing light.

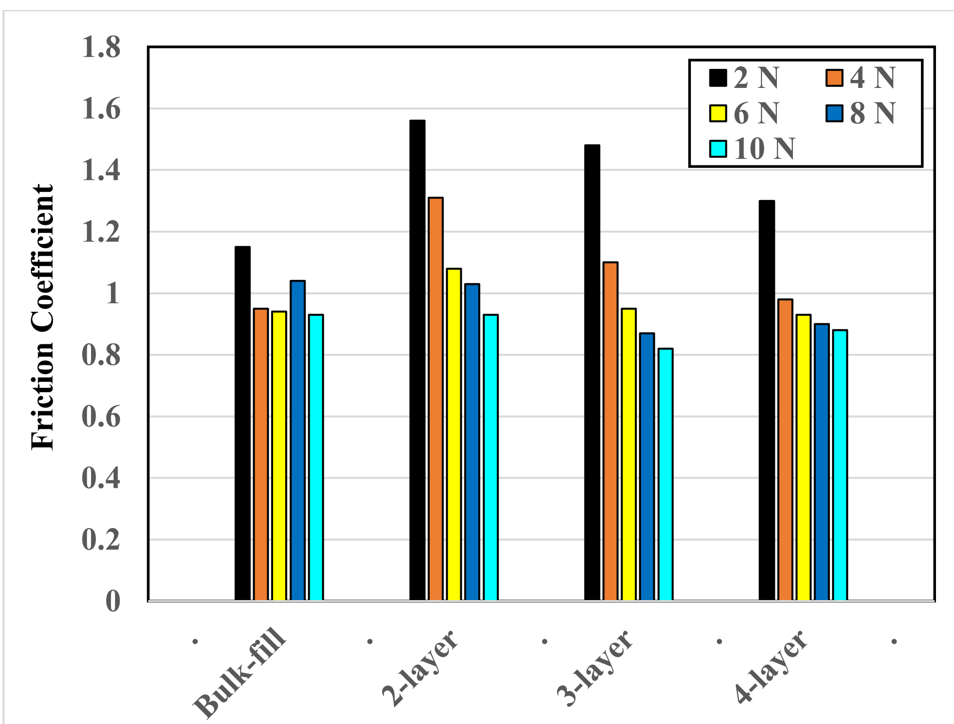

Fig. 3 Friction coefficient displayed by the water wet sliding of test specimen prepared by continuous curing light.

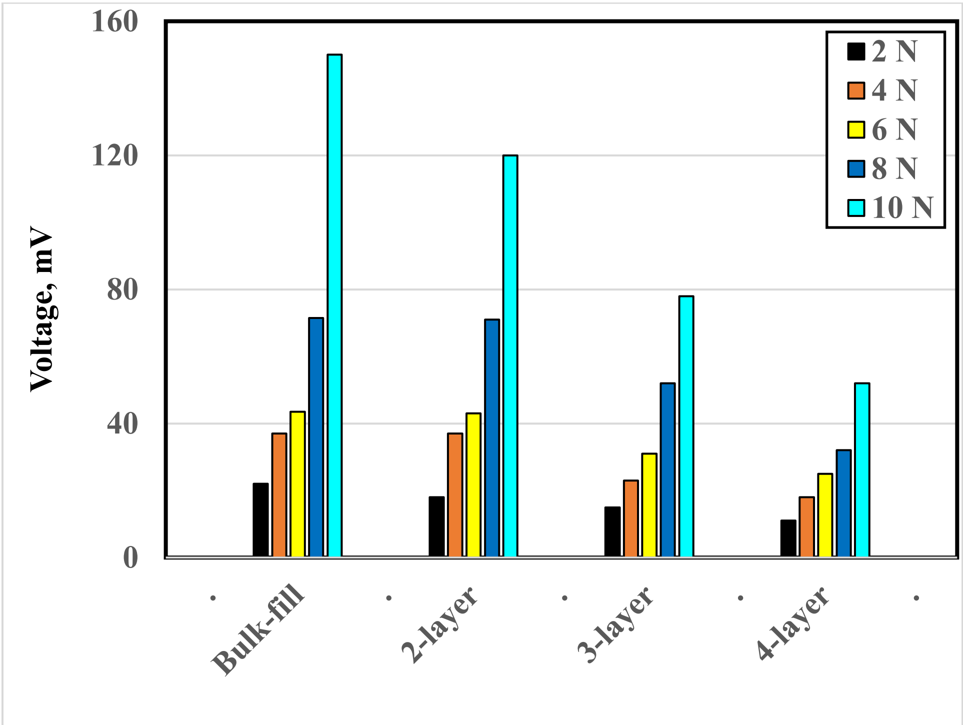

Fig. 4 Voltage generated from the dry sliding of the test specimens prepared by continuous curing light on abrasive paper.

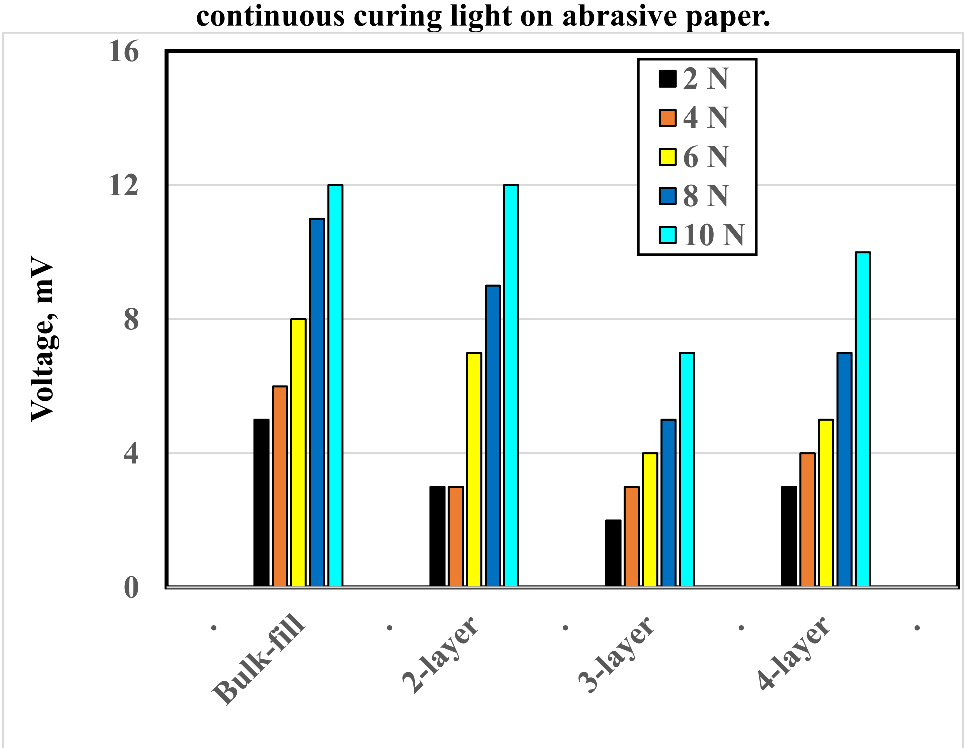

Fig. 5 Voltage generated from the water wet sliding of the test specimens prepared by continuous curing light on abrasive paper.

The results of experiments carried out to investigate the friction coefficient and voltage generated from dry sliding on abrasive paper are shown in Figs. 6 - 9. Test specimens prepared by pulsed curing light and dry slid on abrasive paper displayed relatively lower values than that determined for continuously cured ones, Fig. 6. Bulk fill test specimens displayed the highest friction values, while specimens prepared in four layers showed the lowest friction. Water wet sliding of pulsed light cured test specimens displayed higher friction than that observed in dry sliding, Fig. 7. This behavior can be explained on the bases of the function of water to remove the worn from the surface of abrasive paper. Specimens of multilayers showed higher friction than bulk fill specimens.

Pulsed light cured test specimens dry slid on abrasive paper showed higher voltage values compared to prepared by prepared by continuous light curing, Fig. 8. The highest voltage value was 25 mV displayed by tree layers test specimens at 10 N load. Voltage generated from water wet sliding showed drastic reduction, Fig. 9. The highest voltage value did not exceed 15 mV.

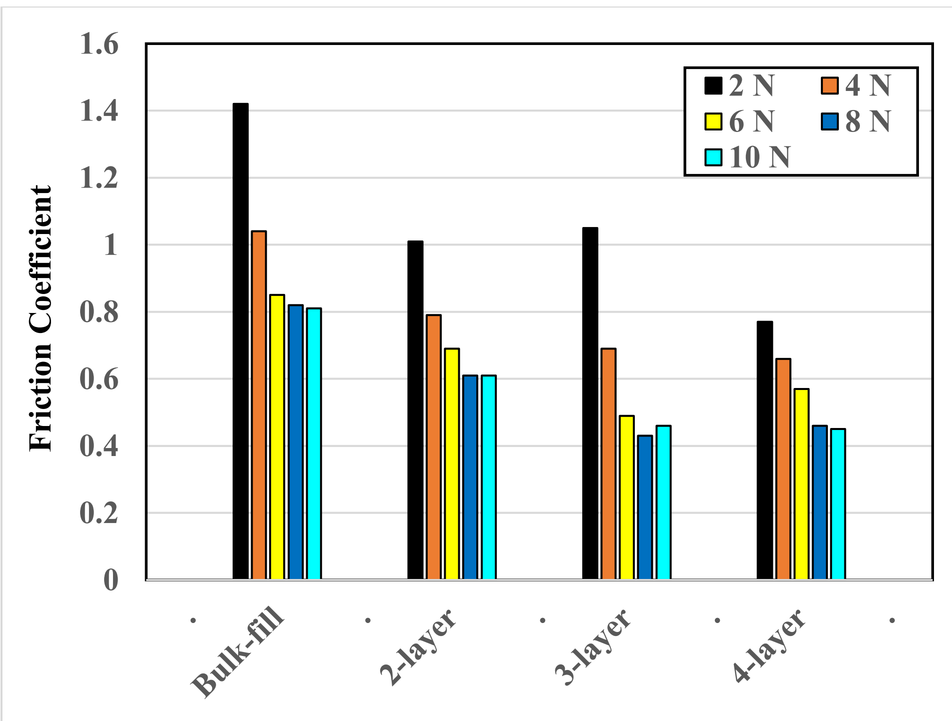

Fig. 6 Friction coefficient displayed by the dry sliding of test specimens prepared by pulsed curing light.

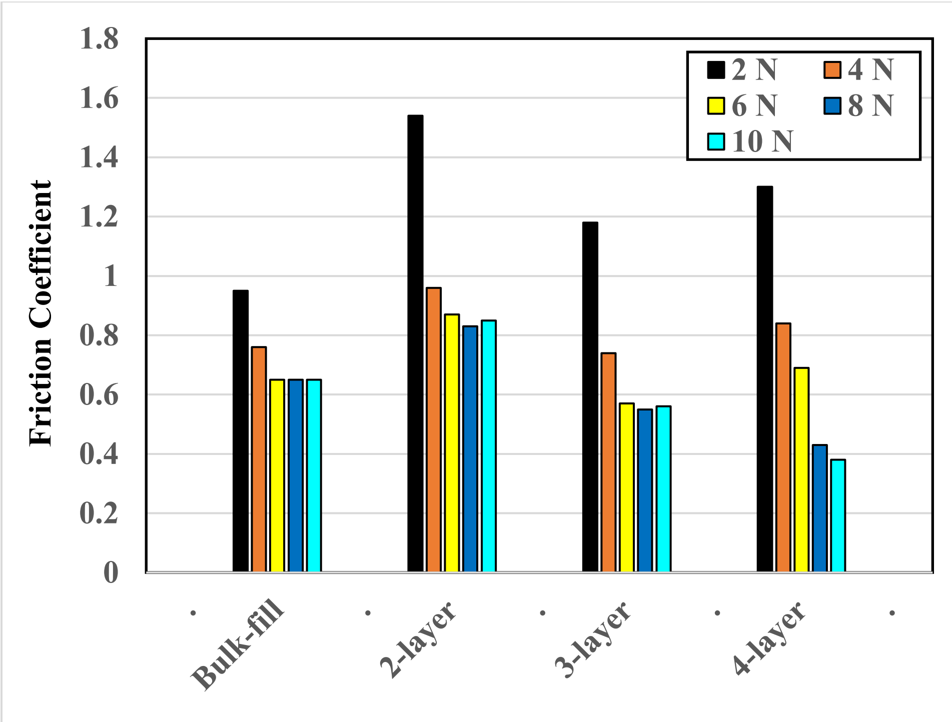

Fig. 7 Friction coefficient displayed by the water wet sliding of test specimens prepared by pulsed curing light.

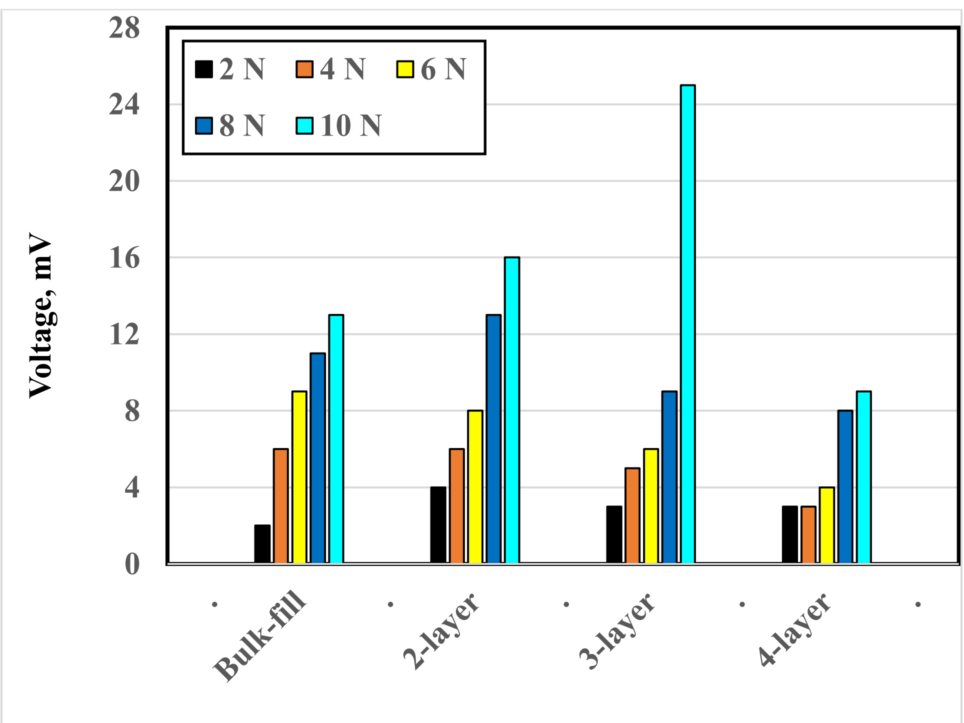

Fig. 8 Voltage generated from the dry sliding of the test specimens prepared by pulsed curing light on abrasive paper.

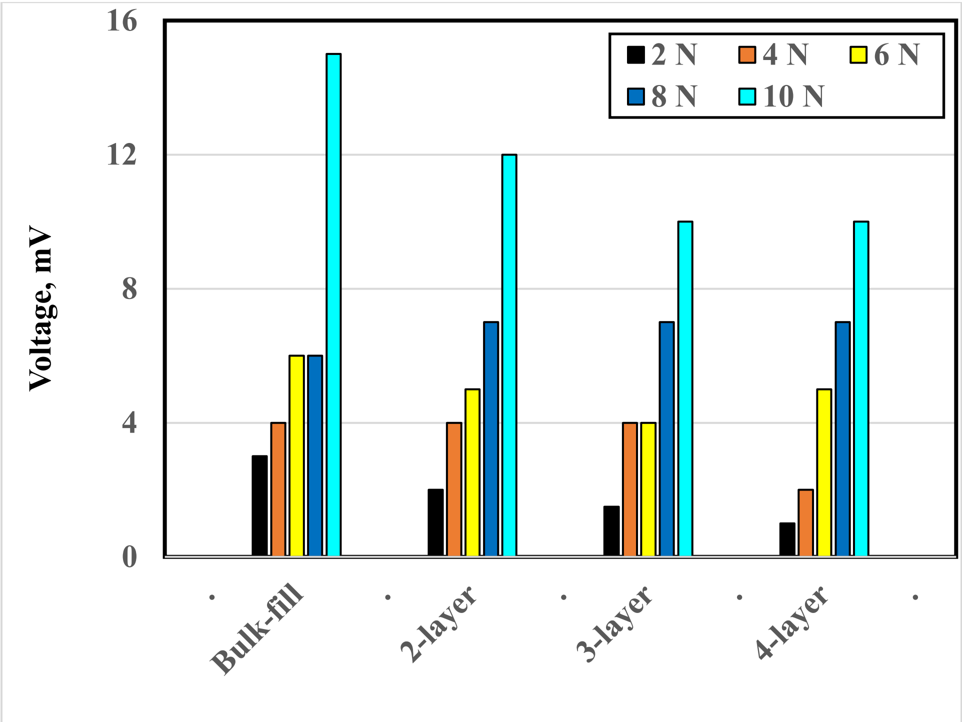

Fig. 9 Voltage generated from the water wet sliding of the test specimens prepared by pulsed curing light on abrasive paper.

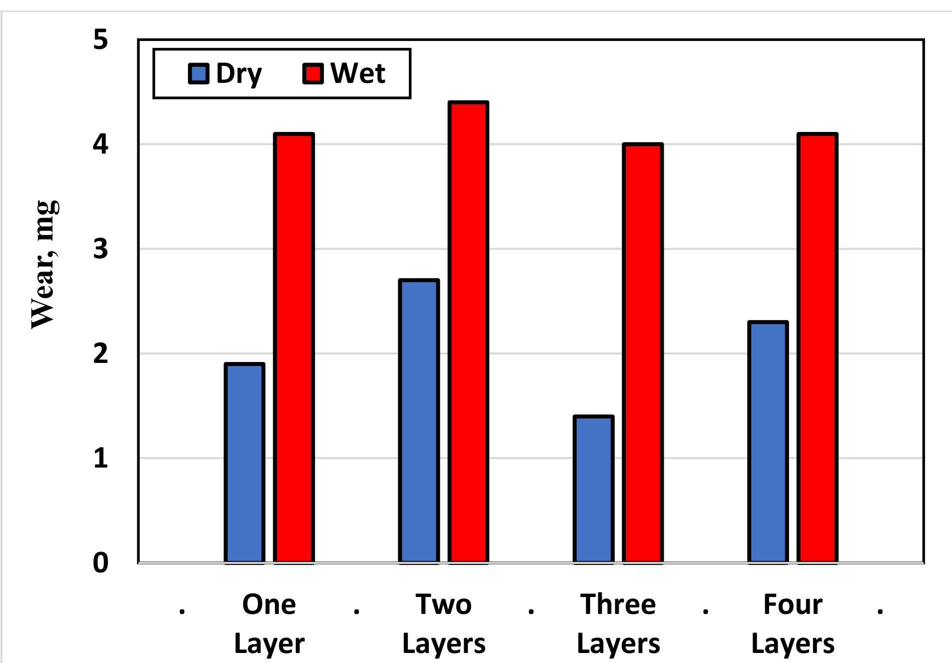

Fig. 10 Wear displayed by the dry and water wet sliding of the test specimens prepared by continuous curing light on abrasive paper.

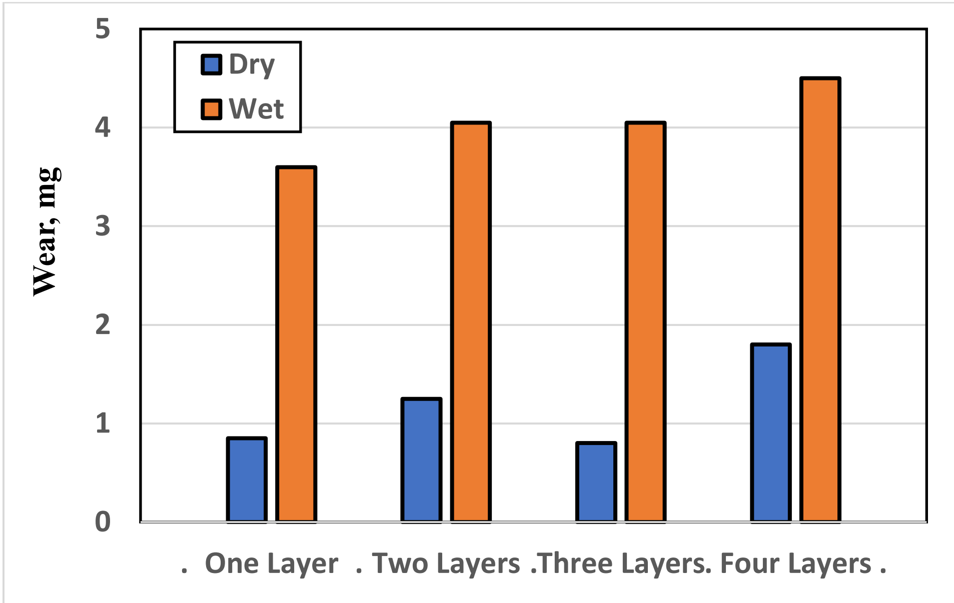

Fig. 11 Wear displayed by the dry and water wet sliding of test specimens prepared by pulsed curing light on abrasive paper.

Figure 10 illustrates the wear of the test specimens prepared by continuous curing light and slid on abrasive paper at dry and water wet sliding conditions. It was observed that wet sliding caused higher wear values that dry sliding. Besides, three layers specimens showed the lowest wear. The presence of water removed the composite resin particles adhered in abrasive paper and made the silicon carbide particles more abrasive. In water wet sliding, Fig. 12, bulk fill specimens displayed the lowest wear values.

CONCLUSIONS

1. Test specimen prepared by continuous curing light of two layers displayed the highest friction values at dry sliding.
2. Friction coefficient decreased by increasing applied load.
3. Test specimens prepared in layers showed higher friction values than the bulk fill ones at water wet sliding, where friction coefficient values were higher than that observed in dry sliding.
4. Voltage values increased as the applied load increased. Bulk fill specimens showed the highest voltage values, while specimens of two, three and four layers showed lower voltage. At water wet sliding, voltage decreased due to the action of water that conducted the current between the two sliding surfaces.
6. Specimens prepared by pulsed curing light displayed lower friction values than that determined for continuously cured ones. At water wet sliding, test specimens displayed higher friction than that observed in dry sliding.

7. Specimens treated by pulsed light showed higher voltage values that that observed for that prepared by continuous light curing, while voltage generated from water wet sliding showed drastic decrease.
9. Water wet sliding caused higher wear values than dry sliding for continuously light cured specimens, while the lowest wear was shown for three layers specimens. Bulk fill specimens showed the lowest wear in water wet sliding.

REFERENCES

1. Farrag A. A., Mousa M. O., Khashaba M., Mohamed M. K., Ali W. Y. and Ameer A. K., "Abrasive Wear Resistance of Composite Resin", Journal of the Egyptian Society of Tribology, Vol. 22, No. 4, October 2025, pp. 1 – 10 (2025).
Journal of the Egyptian Society of Tribology, Vol. 22, No. 3, July 2025, pp. 65 – 79 (2025).
2. Elhejazi Ahmed A., Alosimi A., Alarifi F. and Almuqayrin A., "The effect of depth of cure on microhardness between bulk-fill and hybrid composite resin material", The Saudi Dental Journal 36, pp. 381–385, (2024).
3. Alvanforoush N., Palamara J., Wong R. H. and Burrow M. F., "Comparison between published clinical success of direct resin composite restorations in vital posterior teeth in 1995–2005 and 2006–2016 periods" Aust. Dent. J. 62, pp. 132–145, (2017).
4. Eshmawi Y. T., Al-Zain A. O., Eckert G. J. and Platt J. A., "Variation in composite degree of conversion and microflexural strength for different curing lights and surface locations. J. Am. Dent. Assoc. 149, pp. 893–902, (2018).
5. Ilie N., Hilton T. J., Heintze S. D., Hickel R., Watts D. C., Silikas N., Stansbury J. W., Cadenaro M. and Ferracane J. L., "Academy of dental materials guidance-resin composites: Part Imechanical properties" Dental Mater.: Off. Publication Acad. Dental Mater. 33, pp. 880–894, (2017).
6. Astvaldsdottir A., Dagerhamn J., van Dijken J. W. and Naimi-Akbar A., Sandborgh-Englund G., Tranaeus S. and Nilsson M., Longevity of posterior resin composite restorations in adults – A systematic review. J. Dent. 43, pp. 934 – 954, (2015).
7. Leprince J. G., Palin W. M., Hadis M. A., Devaux J., and Leloup G., "Progress in dimethacrylate-based dental composite technology and curing efficiency" Dental Mater., Off. Publication Acad. Dental Mater. 29, pp. 139–156, (2013).
8. Rueggeberg F. A., Giannini M., Arrais C. A. G. and Price R. B. T., "Light curing in dentistry and clinical implications: A literature review", Braz. Oral. Res. 31, e61, (2017).
9. Keli´c K., Matic S., Marovic D., Klaric E. and Tarle Z., "Microhardness of bulk-fill composite materials", Acta Clin. Croat, pp. 607–613, (2016).
10. Reis A. F., Vestphal M., Amaral R.C., Rodrigues J. A., Roulet J.-F. and Roscoe M. G., "Efficiency of polymerization of bulk-fill composite resins: a systematic review", Br. Oral Res. 31 (suppl 1), (2017).
11. Abbasi M., Moradi Z., Mirzaei M., Kharazifard M. J. and Rezaei S., "Polymerization shrinkage of five bulk-fill composite resins in comparison with a conventional composite resin", J. Dentistry (Tehran, Iran) 15 (6), pp. 365–374, (2018).

12. Kaisarly D. and Gezawi M. E., "Polymerization shrinkage assessment of dental resin composites: a literature review", Odontology 104 (3), pp. 257–270, (2016).
13. Samir N. S., Abdel-Fattah W. M. *and* Adly M. M., "Effect of Light Curing Modes on Polymerization Shrinkage and Marginal Integrity of Different Flowable Bulk-Fill Composites (in vitro study), Alexandria Dental Journal. Volume 46 Issue 2 Section B, pp. 76 – 83, (2020).
14. Alpöz A. R., Ertuğrul F., Cogulu D., Ak A. T., Tanoğlud M. and Kaya E., "Effects of Light Curing Method and Exposure Time on Mechanical Properties of Resin Based Dental Materials", European Journal of Dentistry, Vol. 2, pp. 37 – 42, (2008).
15. Soares C. J., Faria E. S., Rodrigues M. P., Vilela A. B. F., Pfeifer C. S., Tantbirojn D. et al., "Polymerization shrinkage stress of composite resins and resin cements – what do we need to know?", Braz Oral Res, 31, e62, (2017).
16. Davidson C. L., de Gee A. J., "Relaxation of polymerization contraction stresses by flow in dental composites", J Dent Res, 63, pp. 146 - 148, (1984).
17. Ilie N., Hickel R., "Investigations on a methacrylate-based flowable composite based on the SDR technology", Dent Mater;27:348–55, (2011).
18. Weinmann W., Thalacker C., Guggenberger R., "Siloranes in dental composites", Dent Mater, 21, pp. 68 - 74, (2005).
19. Ferracane J. L., "Buonocore lecture, Placing dental composites a stressful experience", Oper Dent, 33, pp. 247 - 57, (2008).
20. Ferracane J. L., Mitchem J. C., "Relationship between composite contraction stress and leakage in Class V cavities", Am J Dent, 16, pp. 239 – 243, PMID 14579877, (2003).
21. Irie M., Suzuki K., Watts D. C., "Marginal gap formation of light-activated restorative materials: effects of immediate setting shrinkage and bond strength", Dent Mater, 18, pp. 203 - 210. PMID: 11823011, (2002).
22. Prager M., Pierce M., Atria P. J., Sampaio C., Caceres E., Wolff M. et al., "Assessment of cuspal deflection and volumetric shrinkage of different bulk fill composites using non-contact phase microscopy and micro-computed tomography", Dent Mater J, 37, pp. 393 - 399, (2018).
23. Singhal S., Gurtu A., Singhal A., Bansal R., Mohan S., "Effect of different composite restorations on the cuspal deflection of premolars restored with different insertion techniques – an in vitro study", J Clin Diag Res, 11, ZC, pp. 67–70, (2017).
24. Daronch M., Rueggeberg F. A., De Goes M. F., "Monomer conversion of pre-heated composite", J Dent Res, 84, pp. 663 - 667, (2005).
25. Lee J. H., Um C. M., Lee I. B., "Rheological properties of resin composites according to variations in monomer and filler composition. Dent Mater, 22, pp. 515 - 526, (2006).
26. Trujillo M., Newman S. M., Stansbury J. W., "Use of near-IR to monitor the influence of external heating on dental composite photopolymerization", Dent Mater, 20, pp. 766 - 77, (2004).
27. Zorzin J., Maier E., Harre S., Fey T., Belli R., Lohbauer U. et al., "Bulk-fill resin composites: polymerization properties and extended light curing", Dent Mater, 31, pp. 293 - 301, (2015).
28. Braga R. R., Ferracane J. L., "Contraction stress related to degree of conversion and reaction kinetics. J Dent Res, 81, pp. 114 – 118, PMID: 11827255, (2002).

29. KILIÇ V., "Polymerization and Light Curing Units in Restorative Dentistry", Chapter 28 in Academic Studies in Health Studies II, Volume 1, First Edition • © HAZİRAN 2020 ISBN • 978-625-7884-59, (2020).
30. Walls A. W., McCabe J. F., "Applied dental materials", United Kingdom: The Blackwell Science Ltd; (2000).
31. Van Noort R., Barbour M. E., "Introduction to Dental Materials, Elsevier Health Sciences; (2013).
32. de Camargo E. J., Moreschi E., Baseggio W., Cury J. A., Pascotto R. C., "Composite depth of cure using four polymerization techniques", Journal of applied oral science, revista FOB.;17(5), pp. 446 - 450, (2009).
33. Roberson T. M., Heymann H., Swift E. J., Sturdevant C. M., "Sturdevant's art and science of operative dentistry", St. Louis, Mo.: Mosby; (2006).
34. Sideridou I., Tserki V., Papanastasiou G., "Effect of chemical structure on degree of conversion in light-cured dimethacrylate-based dental resins", Biomaterials, 23 (8), pp. 1819 - 1829, (2002).
35. Nomoto R., Uchida K., Hirasawa T., "Effect of light intensity on polymerization of light-cured composite resins", Dental materials journal,13 (2), pp. 198 - 205, 72, (1994).
36. Dewaele M., Truffier-Boutry D., Devaux J., Leloup G., "Volume contraction in photocured dental resins: the shrinkage-conversion relationship revisited. Dental materials", official publication of the Academy of Dental Materials, 22 (4), pp. 359 - 365, (2006).
37. Van Noort R., Barbour M., "Introduction to Dental Materials", E-Book, Elsevier Health Sciences, pp.73-75, (2014).
38. Dewaele M., Truffier-Boutry D., Devaux J., Leloup G., "Volume contraction in photocured dental resins: the shrinkage-conversion relationship revisited", Dental Materials, 22(4), pp. 359 - 365, (2006).
39. Craig R., Powers J., "Restorative dental materials", St. Louis, Mosby, Inc; (2002).
40. Roberson T. M., Heymann H., Swift E. J., Sturdevant C. M., "Sturdevant's art and science of operative dentistry", St. Louis, Mosby, (2006).
41. Sakaguchi R. L., Douglas W. H., Peters M. C., "Curing light performance and polymerization of composite restorative materials", Journal of dentistry, 20 (3), pp. 183 - 188, (1992).
42. Yap A. U., "Effectiveness of polymerization in composite restoratives claiming bulk placement: impact of cavity depth and exposure time", Operative dentistry, 25 (2), pp. 113-20, (2000).
43. Mahn E., "Clinical criteria for the successful curing of composite materials", Revista Clínica de Periodoncia, Implantología y Rehabilitación Oral., 6 (3), pp. 148 - 53, (2013).