ประสิทธิภาพการเกิดปฏิกิริยาพอลิเมอร์ของคอมโพสิตเรซินที่อุดครั้งเดียวเต็มโพรงฟันผ่านการวัดความแข็งผิวระดับจุลภาคแบบนูป

Efficacy of Bulk-filled Resin Composite Polymerization via Knoop Microhardness

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บทคัดย่อ

เป็นที่ยอมรับว่าในการอุดคอมโพสิตเรซิน ซึ่งเป็นวัสดุที่แข็งตัวด้วยแสงควรอุดเป็นชั้นๆ เพื่อให้วัสดุแข็งตัวโดยสมบูรณ์ และชดเชยการหดตัวของวัสดุ Sonic fill ™ เป็นวัสดุที่บริษัทแนะนำว่า การฉายแสงเพียงครั้งเดียวสามารถเกิดปฏิกิริยาพอลิเมอร์ได้ ถึงแม้โพรงฟันที่เตรียมจะลึกมากกว่า 2 มม. วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อประเมินประสิทธิภาพการเกิดพอลิเมอร์ของวัสดุดังกล่าว ที่ระดับความลึก 2 , 4, 5 และ 6 มม. นำSonic fill ™ใส่ในแบบจำลองที่มีความลึกดังกล่าวข้างต้น 5 แบบจำลอง/ความลึก ส่วนกลุ่มควบคุมเป็นวัสดุ Premise™ ใส่ในแบบจำลองลึก 2 มม. พร้อมทั้งฉายแสงคอมโพสิตเรซินทุกชิ้นเป็นเวลา 40 วินาที แล้วนำชิ้นตัวอย่างไปเก็บที่ 37° องศา เป็นเวลา 24 ชม. จากนั้นนำไปวัดความแข็งผิวระดับจุลภาคด้วยเครื่องกดนูปน้ำหนัก 100 กรัม 15 วินาที 5 ตำแหน่ง / ตัวอย่างทั้งด้านบนและด้านล่างของชิ้นตัวอย่าง แล้วนำไปหาค่าร้อยละของอัตราส่วนความแข็งผิวระดับจุลภาค ด้านล่างต่อด้านบน ซึ่งยอมรับได้ที่ค่าร้อยละ 80 นำข้อมูลที่วัดได้ไปวิเคราะห์ทางสถิติโดยใช้ t-test และ one-way ANOVA ผลของการศึกษา

พบว่า Sonicfill™ ที่ระดับความลึก 5 มม. และ 6 มม. มีค่าดังกล่าวน้อยว่าร้อยละ 80 ในขณะที่ระดับความลึก 2, 4 มม. และ Premise ™ ระดับความลึก 2 มม. มีค่ามากกว่าร้อยละ 80 และไม่ต่างกันทั้งสามระดับความลึก (*p*>.05) จึงสรุปได้ว่า การเกิดพอลิเมอร์ของ Sonic Fill™ สมบูรณ์ ที่ระดับมากกว่า 2 มม. แต่ไม่ถึง 5 มม. เมื่อประเมินโดยการวัดความแข็งผิวระดับจุลภาค

คำสำคัญ: *เรซินอุดครั้งเดียวเต็มโพรงฟัน ความแข็งผิวระดับจุลภาค ปฏิกิริยาพอลิเมอร์*

Abstract

Resin composite is a light cured-resin based filling material. Incremental layer has been long accepted as a standard technique for placement of dental composite in cavity exceeding 2 mm. This is to ensure complete cure and to decrease amount of shrinkage of resin composite during polymerization. SonicFill™ was claimed by the manufacturer as being able to fully polymerize cavity exceeding 2 mm. in a single increment. The purpose of this study was to determine the effectiveness of polymerization of a bulk-filled composite resin material at depth of cure of 2, 4, 5 and 6 mm. SonicFill™ was placed in disc-shaped specimens of 5 samples per depth and Premise™ at depth of 2 mm were served as control group. All specimens were cured under polyester strips for 40 seconds and stored in 37ºC distilled water for 24hrs. Each specimen was tested by Knoop microhardness tester with 100 grams weight and dwell time of 15 seconds. The data were analyzed for bottom-to-top ration, normally accepted at ≥ 80:100. The data were analyzed statistically by one sample t-test and one-way ANOVA ($p<.05$) using SPSS. The results revealed SonicFill™ at depth 5 and 6 mm with average bottom-to-top ratio of <80:100 compared to Premise™ at depth 2 mm with average bottom-to-top ratio of >80:100. The findings of the present study suggested that the effectiveness of polymerization of bulk-filled composite through microhardness testing was sufficient at depth of cures of 2 and 4 mm but not at 5mm.

Keywords: *Bulk-filled composite, microhardness, polymerization*

1. Introduction

The use of resin composites has increased along with patients' growing demand for dental composites. This demand has been driven in large part by patients' desires in esthetic alternatives to repair carious lesions or traumatized teeth (Ilie et al., 2011).

Resin composites are used for a variety of applications in dentistry, not limited to restorative materials (Ilie et al., 2011). It is likely that the use of these materials will continue to grow both in frequency and type of their applications due to their versatility (Flury et al., 2012).

However, one major drawback of this light-activated resin composite is the degree to which the light can penetrate to cause complete polymerization of the material, which has been termed 'depth of cure'. This has significant influence on both the physical and biological properties of the restoration (Asmussen, 1982a and Caughman et al., 1991).

Incremental layering has been long accepted as the standard of technique for placement of dental composites in cavity preparation exceeding 2 mm. This procedure is based on the desire to ensure complete cure of resin composite from sufficient exposure to the entire increment of material (Flury et al., 2012). Incremental layering technique has one obvious advantage, which is the limitation of the thickness of resin to be penetrated by light, as it has been showed that light penetration decreases when resin thickness increases (Lazarchik et al., 2007). Second, incremental layering technique decreases the amount of shrinkage of resin composite during polymerization (Versluis et al., 1996).

Despite the advantages mentioned above, incremental layering technique also has some flaws. Firstly, it is time consuming due to the time required to place and polymerized each layer. Secondly, the possibilities of incorporating air bubbles and contamination between layers. Thirdly, the likelihood of bond failure between increments. Lastly, the most crucial part is the perfect isolation during these steps must be maintained to guarantee successful restoration (El-Safty et al., 2012 and Flury et al., 2012).

Bulk-filled resin composites allow dentists to skip the time consuming layering process. This type of material has better adaption to the cavity walls. The studies revealed that bulk-filled materials had the lowest shrinkage stress and shrinkage-rate values compared to regular flowable, nanohybrid and microhybrid resin composites (Ilie 2013).

SonicFill™ is claimed to be able to fill up a 5 mm cavity in a single increment without additional composite layer capping. The manufacturers claimed that the sonic activation lowers the viscosity, which allows superior adaptation to cavity wall. Once the activation stops, the material returns to creamy nonsticky handling sculptable state, which allows being carved and contoured for proper anatomy. SonicFill™ is a nanohybrid resin composite with high translucency and less variety of shade available. This system is stored in 0.3 g Unidose® and requires specific handpiece to dispense material (SonicFill™, 2013).

The effectiveness of polymerization may be assessed directly or indirectly. Direct methods that assess degree of conversion such as laser Raman spectroscopy (Asmussen 1982a) and infrared spectroscopy (Asmussen 1982b) have not been accepted for routine use because the methods are complex, expensive and time consuming (Yap, 2000). Indirect methods that assess degree of conversion such as scraping, visual examination and surface hardness (Cook, 1980, Louden and Robets, 1983 and Meyers and Chawla, 1999). Microhardness tests, one of surface hardness testing ,are commonly used because a good correlation between the results of hardness and infrared spectroscopy experiments using Knoop hardness testing were reported (Meyers and Chawla, 1999).Generally the acceptable for resin composite to have the bottom portion cured to the proportion of 80% to the top portion, which is directly at the tip of light source (Asmussen 1982b) .

Knoop has been the most popular method. Its indentation is longer and shallower than Vickers indentation, so a load impression can be applied to brittle materials, such as resin composite, without cracking. Also, the longer diagonal is easier to read than the short diagonal of the Vickers (Murray et al., 1981).

2. Objectives

2.1 To investigate bottom-to-top microhardness ratio of bulk-filled resin composite at the depth of 2, 4, 5, 6 mm. and compare with the conventional resin composite at the depth of 2 mm

2.2 To investigate the influence of depth on microhardness ratio of bulk-filled resin composite.

3. Materials and Methods

3.1 Specimen preparation

Placement of resin composite shade A3, Premise™(Kerr) at depth 2 mm. and SonicFill™ (Kerr) at depth 2, 4, 5 and 6 mm in cylindrical stainless steel mold with dimension of 4 mm. Covered with polyester strip (0.05 mm thick, Stripmat, Polydentia SA CH-6805 Mezzovico, Switzerland) and metal plate. A transfer-loading machine was used to apply 2 kg load to eliminate the excess resin composite. The upper metal plate was removed and then light cured (LED light curing system, Demiplus Kerr, light intensity 1,100 mW/cm^2) for 40 second at the top of the strip perpendicular to the surface.

The samples were stored within dark containers in distilled water (PTT Distilled water) and incubated in Thermostatically controlled incubator (Model Memmert BM 66) at 37°C for 24 hours

3.2 Microhardness testing

For each indentation, a micro-hardness tester (Knoop, FM-ARS 9000, Future-Tech Corp., Kanagawa, Japan), of 100 grams weight with dwell time of 15 seconds was used. The first indentation was made at the center of sample. Four other indentations 1 mm apart from the first indentation were made.

3.3 Data analysis

Kolmogorov-Smirnov test was used to determine if the data was distributed normally. First hypothesis was tested by T-test but for second and third hypothesis were tested by one-way ANOVA. All were done using SPSS.

4. Results

The data showed that Premise™ at depth of 2 mm, and SonicFill™ at depths of 2, 4 mm had average bottom-to-top microhardness ratio is more than 80%. and T-test revealed no statistically significant difference among the groups. However, SonicFill™ had average bottom-to-top microhardness ratios < 80:100 at depths of 5 and 6mm with and T-test revealed significantly difference (Table 1).

The one-way ANOVA analysis of variation of every groups (p<0.05) revealed statistically significant difference (Table 2) and the data revealed that there were statistically significant difference among every groups except SonicFill™ at depth of 2 and 4 mm compared to the control group of Premise™ at depth of 2 mm (Table 3).

Another one-way ANOVA test which compared between groups of SonicFill™ (Table 1.3) showed that there were statistically significant difference (p<0.05) among every group, which revealed the influence of depth on microhardness.

Table 1 One tailed T-test comparison between microhardness ratios of every group with 80%

	Test Value = 80				
	N	Mean	Std. Deviation	t	P
Premise™ 2 mm	25	89.1514	7.8717	5.8130	0.0000
SonicFill™ 2 mm	25	91.9039	4.9925	11.9220	0.0000
SonicFill™ 4 mm	25	82.9081	10.1893	1.4270	0.0832
SonicFill™ 5 mm	25	53.8269	8.6976	-15.0462	0.0000
SonicFill™ 6 mm	25	36.5262	10.6821	-20.3489	0.0000

(* *p -value* < 0.05 is significantly different)

Table 2 Mean differents of one way ANOVA analysis of variation of every groups

	N	Mean (SD)
Premise™ 2 mm	25	89.151 (7.8717)$^{a, b}$
SonicFill™ 2 mm	25	91.904 (4.9925)^{a}
SonicFill™ 4 mm	25	82.908 (10.1893)^{b}
SonicFill™ 5 mm	25	53.827 (8.6976)^{c}
SonicFill™ 6 mm	25	36.526 (10.6821)^{d}

Same superscript indicate homogenous subset (column) ($p < 0.05$)

Table 3 Mean different of one way ANOVA analysis between groups of SonicFill™

	N	Mean (SD)
SonicFill™ 2 mm	25	91.904 (4.9925)^{a}
SonicFill™ 4 mm	25	82.908 (10.1893)^{b}
SonicFill™ 5 mm	25	53.827 (8.6976)^{c}
SonicFill™ 6 mm	25	36.526 (10.6821)^{d}

Same superscript indicate homogenous subset (column) ($p < 0.05$)

5. Discussion

Optimistically, resin composite should be completely polymerized in everyday uses. For the material to be at its best, physically, it must be cured thoroughly. Depth has always been the limitation of photo-activation (Bouschlicher et al., 2004). As light passes the material, its intensity decreases and leads to less polymerization in the deeper portion of the material. However, it is generally acceptable for resin composite to have the bottom portion cured to the proportion of 80% to the top portion, which is directly at the tip of light source (Asmussen, 1982a and Caughman et al., 1991). Depth has always been a concern resulting in practice that resin composite should be restored incrementally of 2 mm each in deep cavity. This is believed to ensure the acceptable conversion rate of the material (Flury et al., 2012, Rueggeberg et al., 1994 and Yap, 2000). New materials that are able to reach the same polymerization rate at higher depths have been developed by the manufacturers. Bulk-filled resin composites emerged claiming to overcome the lowered polymerization levels at increased depths with a variety of brands. Latest of all, SonicFill™ is claimed to be able to polymerized at 5-mm depth and functional (Flury et al., 2012).

Polymerization is the process, which the resin composite becomes functionally ready to withstand the extreme state of oral cavity. The process converts organic monomer into polymer chain (Louden and Roberts, 1983). This can be evaluated both directly and indirectly. The direct method and most sensitive one is to measure the number of double bond between carbon atoms left within the materials but due to its financial costs and technical needs this technique is usually avoided. Indirect methods include scraping technique and surface hardness measurement. The latter is much preferred because of the higher accuracy and cost-effectiveness (Asmussen, 1982a, Asmussen, 1982b, Chuenarrom, 2009, Cook, 1980, Louden and Roberts, 1983, Meyers and Chawla, 1999 Murray et al., 1981 and Yap, 2000).

The higher the degree of conversion is the harder the composite becomes (Alrahlah et al., 2014). The comparison is valid only if the material test is of a single type. Hardness is the resistance towards the deformation and is a physical property of substantial importance in a material such as resin composite, which is needed to tolerate the stress of occlusal forces and mastication. So it can be said that the mechanical properties of resin composites depends on how cured it is.

The result the current study revealed that Premise™ at depth of 2 mm, SonicFill™ at depth of 2 mm and 4 mm had higher bottom-to-top ratio is more than 80% but not at depth of 5 and 6 mm. Our results were not consistent with a previous study, in which the polymerization ratio of 80% was achieved even at the depth of 5 mm (Camargo et al., 2009).

One reason of why 5 mm SonicFill™ hardness ratio was lower than that claimed might be due to the fact that the material must be light-activated from 3 surfaces, top and sideways, with 40 seconds each. In this study, the molds used were made of stainless steel so the light-activation was done only from the top for 40 seconds and this might be the reason for lower hardness. Our results were in contrast to another study, in which several bulk-filled resin composites including SonicFill™ were tested regarding microhardness at a variety of depths by Vicker microhardness tester. The results supported the manufacturer claim's that SonicFill™ can be cured sufficiently at the depth of 5 mm (Leprince et al., 2014).

As often discussed, cavity depth is one of the critical parameters for successful resin composite restorations. This study also evaluated the significant of depth toward the hardness property of SonicFill™. The results of this study suggested that depth has significant importance toward the microhardness like other previous studies. The bottom-to-top microhardness ratio of resin composite tested in this study significantly decreases as the depth increases. This phenomenon has its reasons. As the light travel deeper, it becomes less powerful and less intense so its ability to initiate polymerization of resin composite is lowered (Leprince et al., 2014). This occurred as a result of light dispersion and scattering. They are influenced by the type of the resin composite because of different filler size and distribution affect the penetration of irradiation differently.

Incremental technique has been proposed to overcome problems of depth but bulk-filled composites are meant to eliminate the need of it. So, for the certainty of optimal curing the time used for irradiation can be prolonged as study has shown it can increase the depth of cure (Flury et al., 2012). Post cure treatment by means of irradiation of other surfaces at other depths can also be applied to achieve sufficient polymerization rate.

Translucency is another determining factor for the depth of cure. As claimed by the manufacturer, SonicFill™ has higher translucency than that of Premise™. Thus, allows deeper light penetration and higher depth of cure which correlates with the results of this study. The hardness ratio at depth of 2 mm of SonicFill™ has higher polymerization rate than Premise™ at the same depth (Polydorou et al., 2008 and Rouhoullahi et al., 2012).

6. Conclusion

In the limitations of this study, it can be concluded that the effectiveness of polymerization of bulk-filled resin composite, SonicFill™, is effective at depth of cure more than 2 mm but not to 5 mm as claimed, when evaluated with microhardness test.

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