# Effect of Turbo Light Guide Tip on Curing Depth of Bulk-Fill Resin Composite

Pakorn Chuenjit<sup>1,2\*</sup> Poosit Wongpakorn<sup>1</sup>, Hattaphol Kumchai<sup>1</sup>, Ploypim Kraisintu<sup>1</sup>, Sirapatsorn Thamprasom<sup>1</sup>, Dhunyaporn Treeyasorasai<sup>1</sup>, Nopparada Lawtrakulngam<sup>1</sup> and Kasira Siriyeum<sup>1</sup>

<sup>1</sup>Faculty of Dental Medicine, Rangsit University, 52/347 Meung-ake, Lakhok, Mueng, Pathum thani, 12000, Thailand <sup>2</sup> Nippon Dental University Graduate School of Life Dentistry at Niigata, 1-8 Hamauracho, Chuo-ward,

Niigata city, Niigata prefecture, Japan, 951-8150

\*Corresponding author, e-mail::pakorn@ngt.ndu.ac.jp

### Abstract

This objective of this study was to compare the effects of turbo and standard light guide tip on depth of cures of cure and microhardness ratios in bulk-fill resin composites. A LED light-curing unit was used with two light guide tips: standard and turbo ones. A bulk-fill resin composite was filled inside a stainless steel mold and light-cured for 20 s. Then, the depths of cure of the specimens were measured by the modified scraping method of ISO 4049. Knoop hardness was measured at 0.25 mm intervals to calculate a microhardness ratio in order to estimate the depth of cure. The depth of cure of the turbo tip ( $4.27\pm0.08$  mm) was significantly greater than the standard tip ( $3.61\pm0.08$  mm) when measured by the modified scraping method. At the depth of 4 mm, the turbo and the standard tip produced a microhardness ratio of more than 0.8. However, from 5.0 mm to 6.0 mm, the standard tip produced a microhardness ratio of <0.8 while turbo tip still produced  $\Box 0.8$  to 5.75 mm. In conclusion, the depth of cure of the standard tip was lower than the turbo tip when measured by both methods. For bulk-fill resin composite, the modified scraping method underestimated depths of cure compared to those determined by Knoop hardness profiles.

Keywords: bulk-fill, depth of cure, ISO 4049, resin composite, turbo light guide tip, Knoop microhardness

#### บทคัดย่อ

เพื่อเปรียบเทียบผลปลาขนำแสงแบบเทอร์โบและธรรมคาต่อกวามลึกการบ่มและก่าความแข็งผิวแบบไมโครของเรซินคอมโพสิตชนิดบัลก์ ฟิลล์ เครื่องฉายแสงชนิดแอลอีดีได้รับการใช้กับตัวนำแสงสองชนิด ได้แก่ ตัวนำแสงแบบธรรมดา และแบบเทอร์โบ ทำการอุดเรซินคอมโพสิตชนิด บัลก์ฟิลล์เป็นก้อนเดียวในแบบหล่อเหล็กกล้าไร้สนิม ก่อนฉายแสงเป็นเวลา 20 วินาที จากนั้นทำการวัดความลึกการบ่มของชิ้นงานด้วยวิธีที่ปรับปรุง จาก ISO 4049 และวัดก่ากวามแข็งผิวแบบนูป (Knoop hardness) ที่ระยะห่างทุกๆ 0.25 มม. เพื่อการกำนวณอัตราส่วนของกวามแข็งผิวสำหรับประเมิน ความลึกการบ่มของบัลก์ฟิลล์เรซินคอมโพสิต ด้วยวิธีวัดที่ปรับปรุงมาจาก ISO 4049 ความลึกการบ่มของตัวนำแสงแบบเทอร์โบ (4.27 ± 0.08 มม.) มี ก่าสูงกว่าแบบธรรมดา (3.61 ± 0.08 มม.) และที่ความลึก 4 มม. ตัวนำแสงแบบเทอร์โบและธรรมดามีอัตราส่วนความแข็งผิวมากกว่า 0.8 อย่างไรก็ ตามที่ตลอดความลึก ในช่วง 5-6 มม. ตัวนำแสงแบบธรรมดามีอัตราส่วนความแข็งผิวน้อยกว่า 0.8 ในขณะที่แบบเทอร์โบ ยังคงมีอัตราส่วนความแข็ง ผิวมากกว่า 0.8 จนถึงกวามลึก 5.75 มม. ตัวนำแสงแบบธรรมดาให้ก่าความลึกการบ่มของน้อยกว่าแบบเทอร์โบอย่างมีนัยสำคัญทางสถิติเมื่อวัดโดยวิธีที่ ปรับปรุงมาจาก ISO 4049 และลวามแข็งผิวแบบไมโดร การวัดกวามลึกการบ่มของเรซิน คอมโพสิตชนิดบัลก์ฟิลล์ด้วยวิธีที่ปรับปรุงมาจาก ISO 4049 ใด้ก่าน้อยกว่าเมื่อเทียบกับก่าที่ได้จากการวัดความแข็งผิวแอบไมโล

<mark>คำสำคัญ:</mark> บัลค์ฟิลล์ ความลึกการบ่ม ISO 4049 เรซินคอมโพสิต ตัวนำแสงแบบเทอร์โบ ค่าความแข็งผิวนูป

#### 1. Introduction

Turbo tip is a new design of light guide tip launched several years ago. This tip can transfer blue light from the light source via a bundle of fiber optics to stimulate the photo initiating system in dental materials in an oral cavity. The fiber optics inside a turbo light guide tip is conical-shaped. (Price et al., 2000) The diameter size of fiber optics at the light-source end is longer than an external end. The light emitted from the external side is concentrated because of conical fiber optics; thus, a turbo tip provided higher irradiance than the standard tip. (Price et al., 2000, Nomoto et al., 2004) However, the light density of a turbo tip decreases greatly with an increase in distance from the light source while that of the standard tip decreases gradually (Price et al., 2000). Because light emitted from a turbo tip spreads a wider angle than that from a standard one (Price et al., 2000), a turbo tip provides higher densities ranging from 0 to 4 mm.

However, at a distance between 4 and 10 mm from a light tip, the light densities of a turbo tip were significantly lower than those of a standard one. (Price et al., 2000) The depth of cure of non-bulkfill resin composite is approximately 2-3 mm, (Moore et al., 2008, Camargo et al., 2009, Akram et al., 2011) so each increment is thinner than 3 mm in the filling procedure. Accordingly, a turbo tip can be used to cure a resin composite without concern for a great decrease in light density. (Price et al., 2000, Corciolani et al., 2008)

Recently, a bulk-fill resin composite has been introduced and become a material of choice, providing an easier procedure for dental filling (Alrahlah et al., 2014, Benetti et al., 2014, Garcia et al., 2014). Clinicians can fill a thick bulk of resin composite and light-cure at once because the depth of cure of this new material is approximately 4-5 mm. At these same depths, Price et al. (2000) reported that light densities of a turbo tip were lower than those of a standard one. Turbo tips may not suit the curing of a bulk-fill resin composite due to the fact that light density decreased greatly with increases in distance (Price et al., 2000). In contrast, a standard tip provided lower light irradiance; however, light density decreased in a lower rate compared to the density of a turbo tip (Price et al., 2000). The diameter size of a standard tip is wider than a turbo one; as a result, the standard tip suits the curing of a broad area of dental materials at once without overlapping needed. Nevertheless, most dental cavities, which suit the filling by a resin composite, are much smaller than the diameter size a standard tip. Peripheral part of light was not lit on filling materials when a standard tip was used. (Nitta, 2005, He et al., 2007 Corciolani et al., 2008)

Decreasing light density depends on distances and light tips. Low light density which cannot cure the resin composite deeply enough caused lower mechanical properties and biocompatibility at the bottom filling, leading to an increase in the failure of resin composite. (Calheiros et al., 2008, Durner et al., 2012, Alshali et al., 2013) Depth of cures in bulk-fill resin composites were measured by several studies (AlQahtani et al., 2015, Benetti et al., 2015, Jang et al., 2015). However, manufacturers do not provide instructions of turbo or standard tips. (Ching, 2012, Vivadent, 2014) Accordingly, depth of cures may be different in bulk-fill resin composites when performing light-curing using these two types of light tips. However, there are no studies about this application of light-curing tips in bulk-fill resin composite. The null hypotheses showed that the depth of cure and microhardness profile would not be affected by types of light-curing tips.

#### 2. Objectives

To compare the effects of turbo and standard light guide tips on curing depth and microhardness ratios in bulk-fill resin composites.

## 3. Materials and methods

## 3.1 Depth of cure by modified ISO4049:2009

A depth of cure was measured using a scraping method modified from ISO 4049:2009. Specimens were prepared by injecting a bulk-fill resin composite (3M ESPE GmbH, Seefeld, Germany, A1, Lot number N690323) into a stainless steel split mold with a cylindrical slot (4 mm diameter and 15 mm height) which placed on a dark background covered with a celluloid matrix strip, slightly overfilled to exclude air bubbles. The top of the mold was covered with a celluloid matrix strip and glass slide (1 mm thick), the excess material was removed by pressing a glass slide against the strip. The mold was covered with a specifically designed light tip alignment cover. The cover enabled the light tip (standard and turbo tip, Kerr Corp, Orange, CA, USA) of curing unit to be positioned centrically and perpendicularly to the top of slot and contact the glass slide. The material was light-cured from the top surface for 20 seconds with the power density of 1,100-1,300 mW/cm<sup>2</sup> (Demi<sup>plus</sup>, Kerr Corp, Orange, CA, USA). Before light curing, the power density was checked by radiometer (Model L.E.D. RADIOMETER, sds Kerr, Middleton, WI, USA) to eventually correct by calibration. Ten specimens were light-cured by a standard tip, and ten by a turbo tip.

The specimen was removed from the mold for the scraping test. The soft uncured material at the bottom of the specimen was gently scrapped off with a Silicon carbide grinding paper No.2000. To control the force of scraping, this procedure was performed on the handy lap (HLA-2, Japan). Specimen was held by handy lap's holder, scrapped the uncured material by slide the holder 9 cycles on grinder paper No.2000. The number of cycles was obtained from a pilot study, which has been proved to provide an equal depth of cure, compared to the scraping method from ISO4049:2009. The total weight of the holder and specimen is 109.8 gram-force. The length of the remaining cured material was measured with a micrometer with a

reading accuracy of 0.01 mm for 3 times then averaged and divided by 2 accord to ISO4049:2009 protocol, then recorded as the depth of cure. A single blinded experiment, an experimental method used to ensure impartiality, and avoid errors arising from bias, was performed by two operators who scrapped uncured material off or measure the remaining length of specimens. However, crack or fracture specimen was excluded from an experiment.



Figure 1. Scraping by handy lap and measuring the remaining length of bulk-fill specimen



**Figure 2**. (a) Longitudinal split (b) Indentation pattern for microhardness method. First indentation started at 0.25 until 6 mm depth, by 0.25 mm interval. (c) Knoop hardness profile and the maximum microhardness value.

### 3.2 Microhardness method

All specimens in both groups from previous test were reused. All specimens had remaining length ranged from 6.94 to 8.72 mm. Each specimen was separated by low speed saw into two half-cylindrical specimens symmetrically along longitudinal axis. However, only one half was performed the microhardness test at the cut surface. The cut surface had been wet-grinded by grinding paper on rotary grinder at 150 rpm; 1 minute for each number of grinding paper (No.800, 1200, 1600 and 2000). All specimens were sonicated by ultrasonic cleaner then measured by the Knoop hardness test as a function of depth at 0.25 mm interval as shown in Figure 2. A constant load of 100-gram-force was applied for 15 seconds (FM-ARS 9000, Future-Tech Corp., Japan). The tester computed Knoop hardness automatically and recorded in function of depth as hardness profile. Microhardness values at 4.0, 4.25, 4.5,..., 5.75, 6.0 mm. were divided by maximum values obtained from same specimen into microhardness ratio. The maximum microhardness values were found in some depth from surface. However, one specimen had only one maximum values which common found in range of 0.5 to 3 mm depth.

## 3.3 Data analysis

For scraping method, the normal distributions were tested by Shapiro-Wilk test Statistically significant differences among depth of cure was detected with an independent two-tailed t-test at significant level 0.05. For Microhardness method, the normal distributions were tested by Shapiro-Wilk test. Means of microhardness ratio, at 4 mm depth in each group, were compared between the light guide tips by

independent two-tailed t-test. In addition, all ratios from 4.0 mm to 6.0 mm were compared to 0.8 by onetailed one-sample t-test. The deepest depth which ratio was not less than 0.8 were defined as depth of cure by microhardness method. Moreover, Knoop hardness values were compared in each depth between the standard and the turbo tips by independent two-tailed t-test. All statistics tests were performed at significant level 0.05.

#### 4. Results

By scraping method, the depth of cure of bulk-fill resin composite were 3.61 mm and 4.27 mm, when cured by standard and turbo light guide tips respectively. There was a significant difference in depth of cures between standard and turbo tips (p<0.001) as shown in Table 1 and Figure 3.



Microhardness ratio = hardness value at 4 mm to maximum hardness value. Mean (SD), n=10, independent t-test, significant level 0.05. Difference superscripts indicate significant difference (p<0.001). § indicates no statistical difference (p=0.98)



All of microhardness values were plotted with depth as shown in Figure 4. Means and standard deviations are shown in Table 3, compared between light guide tips in every depths. In both groups, KHN values decreased in increasing of depths. From 0.25 mm to 4.75 mm, there were no statistical differences in KHN between two light tips ( $p \ge 0.10$ ) except at 3.0 mm (p=0.04). The turbo tip had significantly lower KHN than the standard tip. However, the standard tip had significantly lower KHN than the turbo tip ( $p \le 0.048$ ) from 5.0 to 6.0 mm.



Figure 4. Microhardness values plotted with depth (a) standard tip (b) turbo tip.

	Knoop microhardness (N/m²)   Light-curing tip		Sig.
Depth (mm)			
	Standard	Turbo	
0.25	76.27 (6.57)	76.43 (4.80)	0.950
0.50	70.15 (6.27)	75.50 (7.58)	0.103
0.75	72.11 (4.60)	74.32 (5.40)	0.338
1.00	71.19 (7.09)	73.05 (5.34)	0.521
1.25	71.12 (4.16)	72.38 (4.50)	0.490
1.50	74.26 (4.82)	72.44 (4.40)	0.390
1.75	72.72 (6.61)	71.48 (4.17)	0.624
2.00	71.92 (5.13)	70.64 (6.19)	0.619
2.25	71.16 (5.38)	72.29 (6.26)	0.671
2.50	67.83 (7.60)	70.16 (6.50)	0.472
2.75	71.65 (4.01)	69.38 (5.45)	0.304
3.00	70.39 (3.76)	66.31 (4.46)	0.041*
3.25	69.40 (3.40)	69.10 (4.94)	0.877
3.50	70.84 (4.01)	67.88 (4.14)	0.121
3.75	68.48 (7.07)	66.87 (5.47)	0.575
4.00	66.45 (5.39)	66.94 (6.36)	0.855
4.25	65.35 (4.34)	64.46 (4.03)	0.641
4.50	60.96 (5.72)	64.49 (3.03)	0.101
4.75	61.05 (3.87)	63.39 (3.17)	0.157
5.00	59.44 (4.67)	63.54 (3.94)	0.048*
5.25	57.15 (5.36)	61.76 (3.77)	0.039*
5.50	56.19 (4.84)	63.12 (4.31)	0.003*
5.75	55.47 (4.64)	60.31 (3.36)	0.016*
6.00	50.96 (6.65)	61.00 (3.59)	0.001*

Table 2. Comparison of Knoop microhardness between standard and turbo light guide tips.

Mean (SD), n=10

\* indicates significant difference between group, independent t-test at significant level 0.05

From each specimen, the microhardness values from 4 to 6 mm were divided by the maximum microhardness values (Figure 2c.) into microhardness ratios. Manufacturers have recommended the depth of cure of material as 4 mm. The microhardness ratio at 4 mm depth were 0.841 and 0.840 respectively as shown in Table 1 and 3, which had no statistical difference (p=0.98).

Means of microhardness ratio were shown in Table 3, and plotted by depths as shown in Figure 5. From 4.0 mm to 4.75 mm, ratios of standard tip were not statistical less than 0.8 ( $p\Box 0.06$ ). However, from 5.0 mm to 6.0 mm, ratios were significant less than 0.8 ( $p\leq 0.01$ ). On the other hand, ratio of turbo group at 5.75 mm was significant lower than 0.8 (p=0.02), while the others were not statistical lower than 0.8 ( $p\geq 0.05$ ). Accordingly, depth of cure of standard tip was between 4.75 mm and 5.0 mm while the turbo tip was between 5.5 to 5.75 mm approximately as shown as dot lines in Figure 5.

	Standard tip		Turbo tip	
Depth	Microhardness ratio Mean (SD)	p-value	Microhardness ratio Mean (SD)	p-value
4.00	0.8409 (0.0855)	0.08	0.8399 (0.0974)	0.11
4.25	0.8261 (0.0659)	0.12	0.8079 (0.0639)	0.35
4.50	0.7712 (0.0863)	0.16	0.8090 (0.0660)	0.34
4.75	0.7716 (0.0565)	0.07	0.7949 (0.0621)	0.40
5.00	0.7503 (0.0536)	0.009 *	0.7979 (0.0820)	0.47
5.25	0.7235 (0.0821)	0.008 *	0.7758 (0.0801)	0.18
5.50	0.7102 (0.0685)	0.002 *	0.7919 (0.0731)	0.37
5.75	0.7017 (0.0719)	0.001 *	0.7562 (0.0592)	0.02 *
6.00	0.6444 (0.0902)	<0.001 *	0.7649 (0.0619)	0.054

Table 3. Statistical comparisons of microhardness ratio to 0.8 value

\* indicates significant lower than 0.8.

Microhardness ratio = hardness value at interested depth to maximum hardness value), n=10, one-tailed one sample t-test, significant level 0.05.



**Figure 5.** Microhardness ratio (n=10). \* indicates significant lower than 0.8 (one-tail; one sample t-test at significant level 0.05). Whisker bars indicate standard deviations. Vertical dots lines indicate the estimated depth of cure.

## 5. Discussion

By scraping method, depth of cure of standard and turbo tips is 3.611 mm and 4.266 mm respectively. Bulk-fill resin composite cured by turbo tip had more depth of cure than standard tip about 0.655 mm (p<0.001). Nitta measured the depth of cure of non-bulkfill composites cured by standard and turbo tips, which had external diameter sizes of 4 mm, 8 mm and 10 mm respectively (Nitta, 2005). At 20 seconds curing time, the turbo tip provided a significant deeper depth of cure than standard tip. Because the light illuminance of turbo tip was approximately three times of that of the standard tip although it came from the same light source. (Nitta, 2005)

However, Price et al. (2000) evaluated the power density of light from standard and turbo tip and found that the power density decreased as the distance increased. In range of 0 - 3 mm, light density from turbo tip was higher than standard tip. However, the declining rate of light illuminance from turbo tip was greater than that of standard tip. Light density of turbo tip was lower than standard tip at range from 4 mm to 10 mm. (Price et al., 2000) Consequently, the depth of cure of bulk-fill resin composite cured by turbo tip could lower than that of standard tip. In contrast, this current study revealed that depths of cure of turbo tips

were more than standard tips, according to the previous study. (Nitta, 2005) Accordingly, depth of cure may be influenced by other factors.

Diameters of external end of the tips were 11 mm for the standard tip and 8 mm for the turbo one. However, the internal (light source) end diameter was 13 mm for both standard and turbo tips. The light source end was exposed to LEDs inside curing unit, delivered light through light guide tip by bundle of fiber optic, and then, irradiated at the external end. Light was concentrated by conical-shaped fiber optics in turbo light guide tip. Accordingly, irradiance of turbo tips was higher than standard tips because a turbo light tip had a smaller diameter than a standard one at external side. Light beam from a turbo tip was more concentrated than standard one. Accordingly, it provided higher depth of cure than a standard tip. However, light irradiance was lower in peripheral area compared with the central area of the standard light curing tip. (Nomoto et al., 2004, Nitta, 2005) This disadvantage may not much influenced depth of cure of bulk-fill resin composites. Surface microhardness is an indirect measurement of degree of polymerization in resin composite. In current study, Knoop microhardness values were used to evaluate and compare between standard and turbo tip.

To compare a performance of photo polymerization, microhardness value was used to measure the depth starting from 0.25 to 6 mm with 0.25 mm interval. From 0.25 to 4.75 mm depth, there is no statistical difference in hardness value between standard and turbo tip ( $p \ge 0.10$ ), except at 3.0 mm depth (p=0.04) which need a further study. However, most of hardness values of standard tip were significant lower than those of turbo tip in range of 5.0 to 6.0 mm depth ( $p \le 0.048$ ) as shown in Table 3. As a result, turbo tip had a better performance to cure bulk-fill resin composite according to depth of cure from scraping method.

The microhardness ratio can be used to measure the depth of cure of resin composite (Rueggeberg et al., 2000, Tsai et al., 2004, Moore et al., 2008, Akram et al., 2011). In general, bottom to top ratio of hardness value, which should not lower than 0.8 (Tsai et al., 2004, Moore et al., 2008), was used to determine depth of cure and was recommended by manufacturers. However, many studies used the maximum hardness value gathered from all depth, instead of top surface hardness value. (Asmussen and Peutzfeldt, 2003, Frauscher and Ilie, 2012, Leprince et al., 2012, Czasch and Ilie, 2013) It is because top surface of specimen was influenced by oxygen-inhibited and resin-rich layer and maximum hardness values were found in subsurface instead of top surface, this phenomenon happened because polymerization shrinkage to center body of specimen. (Shawkat et al., 2009) In current study, ratios of values at 4.0 mm to maximum were used and compared by t-test. There is no difference in ratio between standard and turbo tip at 4.0 mm. However, this results were obtained from an ideal situation of experimental designs, of which light guide tip almost contacted and perpendicular to resin composite surface. Consequently, hardness ratio at deeper depth was obtained in this study than in clinical situation. For the standard tip, the ratios of hardness values were significant less than 0.8 from 5.0 to 6.0 mm ( $p \le 0.009$ ). While the ratios of turbo tip were significant less than 0.8 at 5.75 mm (p=0.022). This result was according to depth of cure measured by scraping method.

In this study, depth of cure measured by scraping method for standard and turbo tips was 3.61 and 4.27 mm respectively. In result of microhardness method, there were no statistical differences in Knoop hardness values between standard and turbo tips, those obtained from 3.5 to 4.5 mm depths ( $p \ge 0.10$ ). From previous studies, depth of cures from scraping method were significant differences to microhardness method in conventional (non-bulkfill) resin composites (Moore et al., 2008), and according to study in bulk-fill resin composites (Flury et al.,2012).

Manufacturer has recommended 4 mm thickness of each increment when using bulk-fill resin composite. However, depth of cure from scraping method in this study was 3.61 mm when cured by standard tip. Manufacturer recommended curing time at 20 seconds, light irradiance 1,000-2,000 mW/cm<sup>2</sup>, which also performed both in this study. However, there was a 1-mm distance from the light tip to the top surface of the specimen. That was to simulate a clinical situation that a light guide tip cannot be closed to resin composite in Class I or Class II cavities. Consequently, the depth of cure was lower than 4 mm in a standard tip.

In addition, this study used metal mold to prepare specimen. Metal mold provided significant lower depth of cure than polymer mold (Price et al., 2016), because free radical can penetrate from resin

composite to metal mold while polymerizing (Harrington and Wilson, 1993). However, stainless steel mold was chosen to use in this study, followed a guideline from ISO 4049:2009. (ISO, 2009)

Flury et al. (2012) compared depth of cure measurement using two methods in bulk-fill resin composites, which are scraping method and microhardness. It was found that the scraping method was overestimate the depth of cure when compared to microhardness method (Flury et al., 2012). In contrast, this study found that depth of cure measured by microhardness was deeper than scraping method. However, the scraping method is a direct measurement of depth of cure, so the specimen is measured the actual length. On the other hand, microhardness method is a calculation method, which estimated the depth of cure by using ratio and mathematics from microhardness values. Accordingly, depth of cure measured by microhardness is only an approximation. In addition, a shape of specimen was half cylinder in the study of Flury et al. (2012), while that of specimen was a full cylindrical in this study. Therefore, a further study is necessary to determine whether a shape of specimen has effect on depth of cure measurement.

A scraping method has several issues about repeatability, validity, human errors and experimental biases, because scraping of an uncured material was performed by hand. As a result, controlling of force, direction and amount are difficult. Accordingly, there are some modification of methods recommended by ISO 4049:2009 as shown in materials and method section. From a pilot study, a hand-scraping method provided the same remaining length of specimen compared with a modified method.

Finally, a turbo light guide tip is likely to provide a powerful light-curing choice for clinicians and patients, because it can simply fill a deep cavity at once. However, awareness of using this instrument in clinical work is required. For instance, manufacturers have own technologies to improve performance of curing unit, *e.g.*, turbo tip design, various diameter sizes of external guide tips. Such innovations could for better or worse, influence the depth of cure of resin composite.

### 6. Conclusion

A turbo light guide tip can cure bulk-fill resin composite deeper than a standard light guide tip. The small diameter of a turbo tip suits to use in the area difficult to access, such as posterior teeth. However, the small diameter tip is time-consumed to cure the broad area because overlapping light cure is necessary, for example, resin cement in veneer or crown and bridge. In addition, this study performed an ideal situation for experiment. An awareness of using this instrument in clinical work is required.

#### 7. Acknowledgements

This study was financial supported by the Faculty of Dental Medicine, Rangsit university.

### 8. References

- Akram, S., S. Y. Ali Abidi, S. Ahmed, A. A. Meo and F. U. Qazi (2011). Effect of different irradiation times on microhardness and depth of cure of a nanocomposresin. J Coll Physicians Surg Pak 21(7), 411-414.
- AlQahtani, M. Q., P. L. Michaud, B. Sullivan, D. Labrie, M. M. AlShaafi and R. B. Price (2015). Effect of High Irradiance on Depth of Cure of a Conventional and a Bulk Fill Resin-Based Composite. Oper Dent.
- Alrahlah, A., N. Silikas and D. C. Watts (2014). Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater 30(2), 149-154.
- Alshali, R. Z., N. Silikas and J. D. Satterthwaite (2013). Degree of conversion of bulkfill compared to conventional resin-composites at two time intervals. Dent Mater 29(9), e213-217.
- Asmussen, E. and A. Peutzfeldt (2003). Influence of specimen diameter on the relationship between subsurface depth and hardness of a light-cured resin composite. Eur J Oral Sci 111(6), 543-546.
- Benetti, A., C. Havndrup-Pedersen, D. Honore, M. Pedersen and U. Pallesen (2014). Bulk-Fill Resin Composites, Polymerization Contraction, Depth of Cure, and Gap Formation. Oper Dent.
- Benetti, A. R., C. Havndrup-Pedersen, D. Honore, M. K. Pedersen and U. Pallesen (2015). Bulk-fill resin composites, polymerization contraction, depth of cure, and gap formation. Oper Dent 40(2), 190-200.
- Calheiros, F. C., M. Daronch, F. A. Rueggeberg and R. R. Braga (2008). Influence of irradiant energy on degree of conversion, polymerization rate and shrinkage stress in an experimental resin composite system. Dent Mater 24(9): 1164-1168.

Ching, K. (2012). Deep and fast: Kerr's SonicFill bulk fill composite. HDA Now, 24-25.

- Corciolani, G., A. Vichi, C. L. Davidson and M. Ferrari (2008). The influence of tip geometry and distance on light-curing efficacy. Oper Dent 33(3), 325-331.
- Czasch, P. and N. Ilie (2013). In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clin Oral Investig 17(1), 227-235.
- de Camargo, E. J., E. Moreschi, W. Baseggio, J. A. Cury and R. C. Pascotto (2009). Composite depth of cure using four polymerization techniques. J Appl Oral Sci 17(5), 446-450.
- Durner, J., J. Obermaier, M. Draenert and N. Ilie (2012). Correlation of the degree of conversion with the amount of elutable substances in nano-hybrid dental composites. Dent Mater 28(11), 1146-1153.
- Flury, S., S. Hayoz, A. Peutzfeldt, J. Husler and A. Lussi (2012). Depth of cure of resin composites, is the ISO 4049 method suitable for bulk fill materials? Dent Mater 28(5), 521-528.
- Frauscher, K. E. and N. Ilie (2012). Depth of cure and mechanical properties of nanohybrid resin-based composites with novel and conventional matrix formulation. Clinical Oral Investigations 16(5), 1425-1434.
- Garcia, D., P. Yaman, J. Dennison and G. Neiva (2014). Polymerization shrinkage and depth of cure of bulk fill flowable composite resins. Oper Dent 39(4), 441-448.
- Harrington, E. and H. J. Wilson (1993). Depth of cure of radiation-activated materials-effect of mold material and cavity size. J Dent 21(5), 305-311.
- He, Z., Y. Shimada and J. Tagami (2007). The effects of cavity size and incremental technique on microtensile bond strength of resin composite in Class I cavities. Dent Mater 23(5), 533-538. ISO (2009). ISO 4049 Dentistry-Polymer-based filling, restorative and luting materials.
- Jang, J. H., S. H. Park and I. N. Hwang (2015). Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Oper Dent 40(2), 172-180.
- Leprince, J. G., P. Leveque, B. Nysten, B. Gallez, J. Devaux and G. Leloup (2012). New insight into the depth of cure of dimethacrylate-based dental composites. Dent Mater 28(5), 512-520.
- Moore, B. K., J. A. Platt, G. Borges, T. M. Chu and I. Katsilieri (2008). Depth of cure of dental resin composites, ISO 4049 depth and microhardness of types of materials and shades. Oper Dent 33(4), 408-412.
- Nitta, K. (2005). Effect of light guide tip diameter of LED-light curing unit on polymerization of light-cured composites. Dent Mater 21(3), 217-223.
- Nomoto, R., J. F. McCabe and S. Hirano (2004). Effect of aperture size on irradiance of LED curing units. Dent Mater 20(7), 687-692.
- Price, R. B., T. Derand, M. Sedarous, P. Andreou and R. W. Loney (2000). Effect of distance on the power density from two light guides. J Esthet Dent 12(6), 320-327.
- Price, R. B., F. A. Rueggeberg, J. Harlow and B. Sullivan (2016). Effect of mold type, diameter, and uncured composite removal method on depth of cure. Clin Oral Investig 20(7), 1699-1707.
- Rueggeberg, F. A., J. W. Ergle and D. J. Mettenburg (2000). Polymerization depths of contemporary lightcuring units using microhardness. J Esthet Dent 12(6), 340-349.
- Shawkat, E. S., A. C. Shortall, O. Addison and W. M. Palin (2009). Oxygen inhibition and incremental layer bond strengths of resin composites. Dent Mater 25(11), 1338-1346.
- Tsai, P. C. L., I. A. Meyers and L. J. Walsh (2004). Depth of cure and surface microhardness of composite resin cured with blue LED curing lights. Dental Materials 20(4), 364-369.
- Vivadent, I. (2014). Tetric EvoCeram(R) Bulk fill, simplifies composite restoration placement, increases efficiency. Compend Contin Educ Dent 35(6), 432.