Influence of Light Curing Energy on Dentin Bond Strength

NOZU Shigeo, MATSUDA Tomoyuki, IWATA Naohiro, YOSHIKAWA Kazushi and YAMAMOTO Kazuyo

Department of Operative Dentistry, Osaka Dental University

野津繁生，松田有之，岩田有弘，吉川一志，山本一世
第 142 回日本歯科保存学会学術学会（平成 27 年 6 月 25 日、北九州市）

Influence of Light Curing Energy on Dentin Bond Strength

NOZU Shigeo, MATSUDA Tomoyuki, IWATA Naohiro, YOSHIKAWA Kazushi and YAMAMOTO Kazuyo

Department of Operative Dentistry, Osaka Dental University.

Abstract

Purpose : Treatment based on the MI concept has recently become generally performed, and restoration treatment using composite resin (CR) has increased. In the molar regions, CR restoration is widely applied to class II cavities. However, in these cavities, a septum, such as sectional matrix, is attached corresponding to the anatomical morphology of the tooth, simultaneously with formation of a cavity with a narrow width minimizing tooth grinding for MI, through which light for polymerization is unlikely to reach the gingival side wall in the deepest region of the cavity. In this study, using halogen-type and light-emitting diode (LED) irradiators, we measured the tensile bond strength at various irradiation distances and light intensities to investigate the influence of irradiation energy of the irradiator on the bond strength of CR restoration.

Methods : For the irradiator, a halogen-type irradiator, Curing Light XL3000 (3M ESPE, XL) and LED-type irradiators, Elipar™ S10 (3M ESPE, S10) and PENCURE 2000 (Morita MFG, PC) were used. Light irradiation using PENCURE 2000 was applied using the normal mode (PC-N) and high-power mode (PC-H).

Results : When light was irradiated from the lingual direction at 60° to the occlusal surface, the light intensity significantly decreased using any irradiator, compared with that at an irradiation angle of 90°. When the irradiation distance was increased from 2 to 7, 12, and 22 mm, the light intensity decreased using any irradiator, and the bond strength also decreased. When the light intensity of the irradiators was increased from 100 to 200, 400, and 600 mW/cm^2, the bond strength improved. When the light intensity of the irradiators was set at 100, 200, 400, and 600 mW/cm^2 and the irradiation time was prolonged so as to obtain a uniform amount of light energy, the bond strength at the light intensity of 100 and 200 mW/cm^2 significantly decreased compared with that of 600 mW/cm^2 although the irradiation time was increased.

Conclusion : Based on the above findings, for composite filling in class II cavities of the molars, it may be desirable to use an irradiator with a light intensity of 400 mW/cm^2 or higher, and increase the irradiation time as much as possible in each step of irradiation.

Key words :　light intensity, light curing distance, dentin bond strength

Corresponding author: Dr. Yoshikawa, Department of Operative Dentistry, Osaka Dental University
8-1 Kuzuha-hanazonocho, Hirakata, Osaka 573-1121, Japan
TEL: +81-72-864-3077, FAX: +81-72-864-3177
E-mail: kazushi@cc.osaka-dent.ac.jp

Introduction

With recent improvement of the dentin adhesive system and physical properties of composite resin, MI concept-based treatment has become generally performed[1-3], and restoration treatment using composite resin (CR) has increased. In the molar regions, CR restoration is widely applied to class II cavities[4-6]. However, a septum, such as sectional matrix, is attached corresponding to the anatomical morphology of the tooth in class II cavities of the molars, simultaneously with formation of a cavity with a narrow width minimizing tooth grinding for MI, through which light for polymerization is unlikely to reach the gingival side wall in the deepest region of the cavity. Moreover, irradiation cannot be applied from directly above because the irradiator is blocked by the cusp due to the occlusal relationship with the opposite tooth, septum or a tool retaining the septum, and a rubberdam clamp, which may result in oblique or distant irradiation[7]. It is questionable how much the light reaches the deepest region of the cavity, and reduction of light intensity may influence the tooth adhesiveness[4,5,8,9].

In this study, using halogen-type and light-emitting diode (LED) irradiators, we measured the tensile bond strength at various irradiation distances and light intensities to investigate the influences of irradiation energy of the irradiators on the bond strength of CR restoration.

Materials and Methods

The irradiators used in the experiments are shown in Table 1.

For the irradiator, a halogen-type irradiator, Curing Light XL3000 (3M ESPE, XL) and LED-type irradiators, Elipar™ S10 (3M ESPE, S10) and PENCURE 2000 (Morita MFG, PC) were used. Light irradiation using PENCURE 2000 was applied using the normal mode (PC-N) and high-power mode (PC-H).

1. Measurement of light intensity of the irradiators

Experiment 1: Measurement of light intensity by irradiation distance

To investigate the influence of the irradiation distance on the light intensity of the irradiators, the distance between the light receiver of a light intensity measurement device and irradiated surface was set at 2, 7, 12, and 22 mm for each irradiator, a metal jig with a 3-mm inner diameter and 2-mm height used in the adhesion test was set to the light receiver, and the light intensity was measured. For the light intensity measurement device, a spectroscope, Quest™ X (KONICA MINOLTA), was used.

Experiment 2: Measurement of light intensity by irradiation angle

To investigate the influence of auxiliary tools used for the septum in CR restoration on the light intensity of the irradiators, an epoxy model reproducing a class II cavity of the right lower first molar was prepared, and the light intensity was measured. To measure the intensity of irradiated light on the region corresponding to the gingival side wall of the proximal step of a class II cavity, a class II cavity with a 3-mm diameter and 6-mm depth was prepared in the distal region of the right lower first molar of the epoxy model, and the model was prepared so that the light receiver of a light intensity measurement device could be placed through the bottom of the model (Fig. 1). For the light intensity measurement device, a spectroscope, Quest™ X (KONICA MINOLTA), was used. To set a septum in the cavity-formed model tooth, sectional matrix was used as an auxiliary tool, the gingival side wall of the proximal step was irradiated under the following irradiation conditions, and the light intensity was measured: An irradiation angle of 90° to the occlusal surface, or 60° to the occlusal surface from the lingual direction (Fig. 2). Measurement was repeated 3 times under each condition, and statistical analysis was performed using one-way layout analysis of variance and Scheffe's test ($p<0.05$).

2. Measurement of dentin bond strength under various irradiation conditions

Preparation of adherend surface

A frozen extracted bovine tooth was thawed under running water. The labial side of the crown was cut using a model trimmer to flatten the dentin surface, and polished with waterproof abrasive paper in the order of #320 and #600, and this was used as a dentin adherend surface. A metal jig with a 3-mm inner diameter and 2-mm height was fixed to the dentin adherend surface with double-sided tape, to specify the adherend area.

Adhesion conditions

The materials used in the experiment are shown in Table 2.

For the dentin adhesive system, CLEARFIL® MEGA BOND® (Kuraray Noritake Dental, MB) was used. The tooth surface was processed following the manufacturer's instruction: The primer was applied for 20 seconds, followed by low-pressure air blow for 5 seconds and high-pressure air blow for 5 seconds. The bonding was then applied and the coating thickness was made homogenous by low-pressure air blow. Light irradiation was applied under the irradiation conditions of each experiment. A commercial CR was then filled in the jig under the irradiation conditions of each experiment. For CR, CLEARFIL® AP-X Shade A3 (Kuraray Noritake Dental, APX) was used.

Experiment 1: Influence of irradiation distance on bond strength

To investigate the influence of the irradiation distance on the bond strength of CR restoration, various irradiation distances to the bonding and CR were set, and the tensile bond strength was measured. Regarding the irradiation conditions, the distance between the dentin adherend surface and surface irradiated by each irradiator was set at 2, 7, 12, and 22 mm, and MB and APX were irradiated for 10 and 20 seconds, respectively, using each irradiator.

Experiment 2: Influence of light intensity on bond strength

To investigate the influence of the light intensity of irradiation on the bond strength of CR restoration, the intensity of light irradiated to the bonding and CR was specified, and the tensile bond strength was measured. PENCURE 2000 was modified by Morita MFG, and a prototype LED irradiator (prototype PC) with adjustable light intensity was prepared. Regarding the irradiation conditions, this experiment was performed using only the normal mode, and the distance between the dentin adherend surface and surface irradiated by the irradiator was set at 2 mm. The light intensity of the prototype PC was measured using a spectroscope, Quest™ X (KONICA MINOLTA). The light intensity was set at 100, 200, 400, 600, 800, and 1000mW/cm^2, and MB and APX were irradiated for 10 and 20 seconds, respectively.

Experiment 3: Influence of the amount of light energy (light intensity and irradiation time) on bond strength

To investigate the influence of the light intensity and irradiation time on the bond strength of CR restoration, these of light irradiation applied to the bonding and CR were specified, and the tensile bond strength was measured. For the irradiator, the prototype PC with adjustable light intensity was used, as in Experiment 2. Regarding the irradiation conditions, this experiment was performed using only the normal mode, the distance between the dentin adherend surface and surface irradiated by the irradiator was set at 2 mm, and the irradiation time was set under the following conditions. The irradiation conditions of 600 mW/cm^2 applied to MB and APX for 10 and 20 seconds, respectively, were regarded as control groups, and the total energy of irradiated light was uniform with that of the control groups, i.e., for irradiation at 100 mW/cm^2, the irradiation time was extended 6-times (60 and 120 seconds for MB and APX, respectively), for irradiation at 200 mW/cm^2, the irradiation time was extended 3-times (30 and 60 seconds for MB and APX, respectively), and for irradiation at 400 mW/cm^2, the irradiation time was extended 1.5-times (15 and 30 seconds for MB and APX, respectively). The number of samples was 5 for each condition.

Measurement of tensile bond strength and statistical analysis

Prepared adhered samples were stored in 37℃ water for 24 hours, and then subjected to tensile bond strength measurement at CHS=0.3 mm/min using a tension testing machine, IM-20 (INTESCO). Five samples were measured under each condition, and statistical analysis was performed using one-way layout analysis of variance and Scheffe's test ($p<0.05$).

Observation of fracture surface after adhesion test

After tensile bond strength measurement, the fracture surface was coated with gold vapor deposition using an ion sputtering device, JFC-1500 (JEOL), and observed under a scanning electron microscope, JSM-5610 (JEOL).

Results

1. Measurement of light intensity of irradiators

Experiment 1: Measurement of light intensity by irradiation distance

The light intensity measured at each irradiation distance is shown in Fig. 3.

The intensity of light emitted by any irradiator significantly decreased as the irradiation distance increased.

Experiment 2: Measurement of light intensity by irradiation angle

The light intensity measured at each irradiation angle is shown in Fig. 4.

Using any irradiator, when light was emitted at 60° to the occlusal surface, the light intensity significantly decreased compared with that at 90°.

2. Measurement of dentin bond strength under various irradiation conditions

Experiment 1: Influence of irradiation distance on bond strength

The results of tensile bond strength measurement are shown in Fig. 5.

Using any irradiator, the bond strength decreased as the irradiation distance increased. The bond strength significantly decreased when the irradiation distance was 22 mm compared with that at an irradiation distance of 2 mm. No significant difference was noted at an irradiation distance of 7 or 12 mm compared with that at 2 mm.

The results of fracture surface observation are shown in Tables 3.

Using any irradiator, dentin cohesive failure or mixed failure was frequently observed when the irradiation distance was short, and interfacial or resin cohesive failure increased with the irradiation distance.

Experiment 2: Influence of light intensity on bond strength

The results of tensile bond strength measurement are shown in Fig. 6.

The tensile bond strength increased with the light intensity up to 600 mW/cm^2. The increase was significant at 400, 600, 800, and 1000mW/cm^2 compared with that at 100 mW/cm^2, and at 600, 800, and 1000 mW/cm^2 compared with that at 200 mW/cm^2.

The results of fracture surface observation are shown in Table 4.

Using any irradiator, interfacial or resin cohesion failure was frequently observed when the light intensity was low, and dentin cohesion or mixed failure increased with the light intensity.

Experiment 3: Influence of the amount of light energy (light intensity and irradiation time) on bond strength

The results of tensile bond strength measurement are shown in Fig. 7.

When the total amount of light energy emitted was specified, compared with the tensile bond strength at 600 mW/cm^2, the strength decreased at the other light intensities, and the decrease was significant at 100 and 200 mW/cm^2 compared with that at 600 mW/cm^2.

The results of fracture surface observation are shown in Table 5.

When the total amount of light energy emitted was specified, resin cohesion failure was frequently observed at 100 mW/cm^2. Dentin cohesion or mixed failure increased with the light intensity.

Discussion

For visible light-cured CR, camphorquinone is used as a polymerization initiator. A photosensitizer, camphorquinone, absorbs about 470 nm wavelength light, being excited, and initiates polymerization through acting on the polymerization initiator, tertiary amine. Accordingly, an irradiator with a peak light wavelength near 470 nm is necessary to polymerize visible light-cured CR.

Halogen lamps have been used as a light source from the beginning of camphorquinone use. It is an incandescent light bulb and its light-emitting mode is the same as that of electric bulbs used in homes. Halogen lamps emit about 370-nm low-wavelength light near ultraviolet light over 700-nm visible light and longer-wavelength infrared light. Since long-wavelength light, such as infrared light, generates heat in irradiated photo-curing materials and teeth, it is removed using a filter. The wavelength after passing through a filter is about 400-500 nm. Since halogen lamps generate a large amount of heat and require a fan to cool the electric bulb, the gun type is frequently used, but it is wired and has a large irradiation part, with which the molar region may be difficult to irradiate.

Irradiators have been developed as the demand for CR restoration increased, and high-output, cordless, and lightweight irradiators have been developed, aiming at shortening of treatment time, simplifying operation, and economic improvement, for example, a plasma irradiator capable of shortening the irradiation time for CR polymerization using plasma beam, and a cordless, lightweight LED irradiator with improved economic efficiency[10] . The pace of LED irradiator development is rapid. LED irradiators emit light of a specific wavelength range[11] , unlike halogen light, which has advantages and disadvantages. The advantages are: emission of light within a wavelength range appropriate for CR polymerization from a solid light source, low electricity consumption compared with that of the conventional halogen irradiator, and long durability of the light source[11] . In addition, many products have a pen shape because a filter to remove the extra wavelength range is unnecessary because of low heat generation, with which the molar region can be easily irradiated[12,13] . Regarding disadvantages, it was previously possible that polymerization is insufficient when the light absorption region of a sensitizer contained in light-cured materials, such as CR and bonding materials, is present outside the wavelength range of light emitted by LED[14,15] , but now, another polymerization initiator with a different sensitization range is contained, in addition to camphoquinone, improving polymerization. A lack of the light intensity of LED irradiators was also a previous concerned, but a product with an irradiation intensity higher than that of halogen visible light irradiators has recently been launched[16] . Indeed, the intensity of the LED light source was higher than that of the halogen light source in this study. The light intensity was measured on the assumption that irradiation from right above is difficult due to the occlusal relationship with the opposite tooth and interference with various tools. When irradiation was applied from the lingual direction at an irradiation angle of 60° to the occlusal surface, the light intensity significant decreased compared with that at 90°, using any irradiator. Since a sectional matrix was used as a septum in this experiment, it was difficult for light to linearly reach the light receiver-attached gingival side wall from the occlusal surface direction. Irradiation should be applied vertically to the irradiation field, but it may be difficult in actual clinical practice[7]. A pen-type irradiator with a small emitter easy to handle during irradiation should be selected.

In the light intensity measurement of the irradiators, it was measured with an increase in the irradiation distance. Using any irradiator, the light intensity decreased as the irradiation distance increased. Since light is attenuated in inverse proportion to square of the distance, irradiation should be applied from a site as near as possible, but setting an irradiator close to the target is difficult in clinical practice[7]. Regarding the influence of the irradiation distance on adhesion, using any irradiator, the bond strength decreased as the irradiation distance increased, and interfacial or resin cohesion failure increased on the fracture surface. Regarding the influence of the light intensity on adhesion, using any irradiator, the tensile bond strength decreased at 100 and 200 mW/cm^2, and interfacial or resin cohesion failure was frequently observed on the fracture surface, suggesting that, regardless of the cause being either the irradiation distance or light intensity of the irradiator, attenuation of the light intensity reaching the adherend surface prevented polymerization of the bonding material or CR, or caused heterogeneous polymerization, forming a vulnerable region in the adhesion layer[17,18]. Regarding adhesion with the tooth, polymerization induced by each step of irradiation may have occurred in each of the resin-impregnated layer, bonding material, and CR in the adhesive interface. When a vulnerable region is formed in some parts of the adhesive layers, various stresses may be finally concentrate in the most vulnerable layer and destroy it. Thus, sufficient polymerization of all adhesive layers is essential[19-25].

Theoretically, the resin polymerization rate is determined by the amount of light energy irradiated. The amount of light energy is the product of the light intensity and irradiation time (amount of light energy = light intensity x irradiation time). It is considered that when the amount of light energy is the same, the rate of resin polymerization induced by light emitted by an irradiator is the same between irradiations at a low light intensity for a long irradiation time and at a high light intensity for a short time[26,27)]. However, in the adhesion test of Experiment 3, the tensile bond strength did not completely recover even though the irradiation time was prolonged, suggesting that although the resin polymerization rate may recover when the amount of light energy is the same, adhesion with the tooth did not occur in the theoretical pattern because polymerization behavior differs among the adhesive layers.

For countermeasures, based on these results, it may be necessary to use an irradiator with a light intensity of 400 mW/cm^2 or higher and increase the irradiation time in each step as much as possible, or use a high-output irradiator as much as possible, for which identification of the light intensity of an irradiator used is necessary to determine the irradiation time. In addition, it is important to constantly confirm that a specific light intensity is obtained because the light intensity decreases when the tip of the irradiator is damaged or adhered with resin.

Conclusion

To investigate the influence of the light intensity of irradiators on dentin adhesiveness, light intensity measurement at various irradiation distances and angles and tensile bond strength tests were performed, and the destruction pattern was evaluated after the test.

1. When light was irradiated from the lingual direction at 60° to the occlusal surface, the light intensity significantly decreased using any irradiator, compared with that at an irradiation angle of 90°.
2. When the irradiation distance was increased from 2 to 7, 12, and 22 mm, the light intensity decreased using any irradiator, and the bond strength also decreased.
3. When the light intensity of the irradiators was increased from 100 to 200, 400, and 600 mW/cm^2, the bond strength improved.
4. When the light intensity of the irradiators was set at 100, 200, 400, and 600 mW/cm^2 and the irradiation time was increased so as to obtain a uniform amount of light energy, the bond strength at the light intensity of 100 and 200 mW/cm^2 significantly decreased compared with that of 600 mW/cm^2 although the irradiation time was increased.

Based on the above findings, for composite filling in class II cavities of the molars, it may be necessary to use an irradiator with a light intensity of 400 mW/cm^2 or higher and increase the irradiation time as much as possible in each step of irradiation.

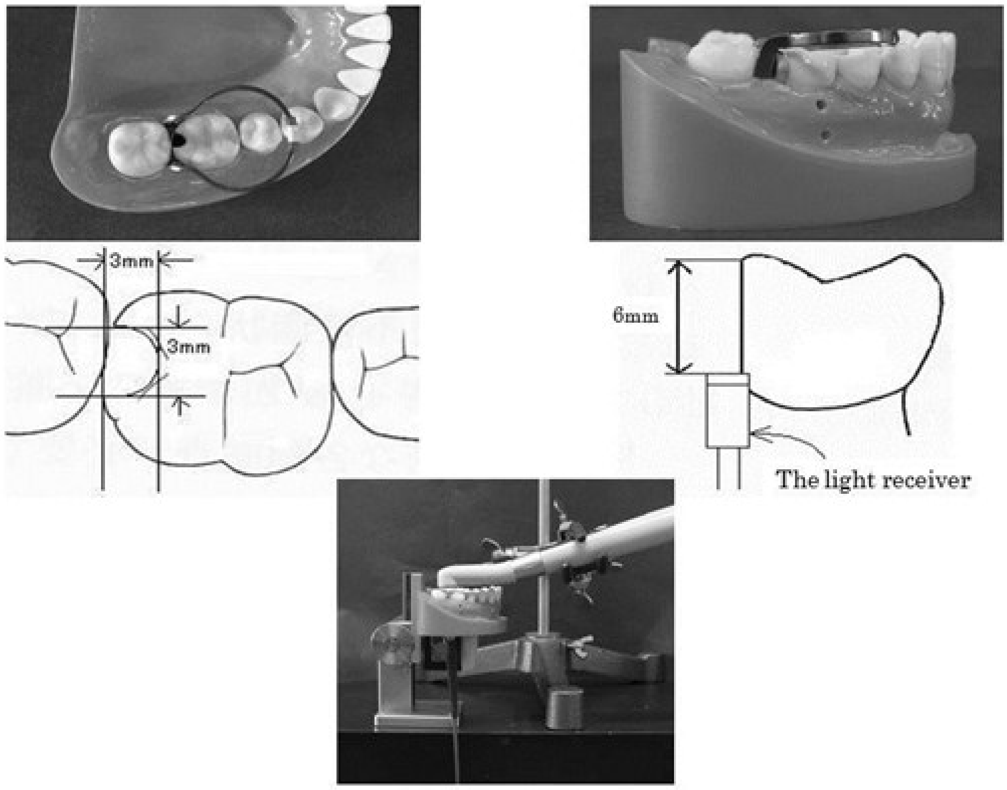

Fig. 1 Devices for measuring light intensity of irradiators

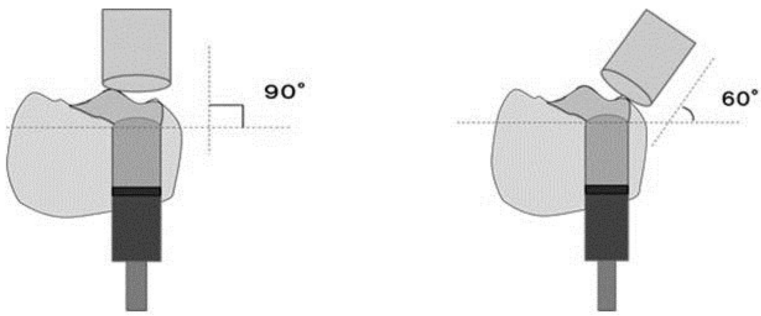

Fig. 2 Irradiation angle of irradiators for measuring light intensity

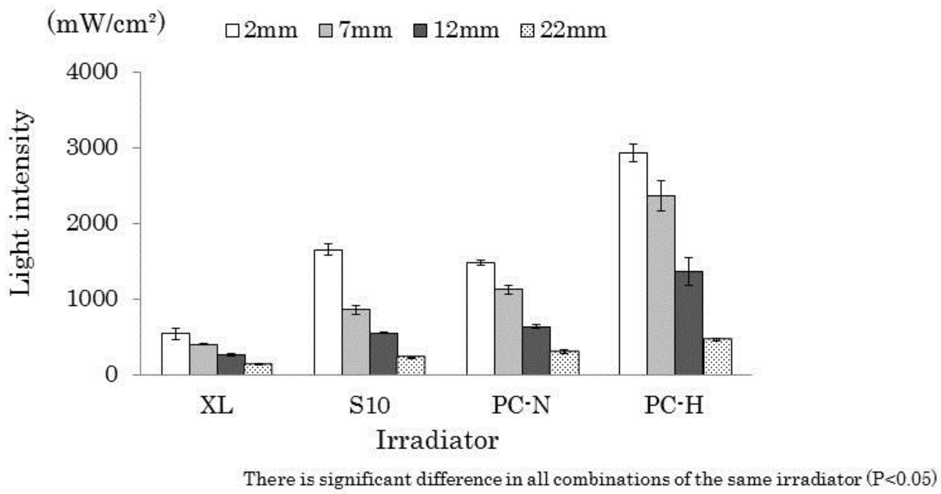

Fig. 3 The light intensity of irradiator measured at each irradiation distance

The intensity of light emitted by any irradiator significantly decreased as the irradiation distance increased.

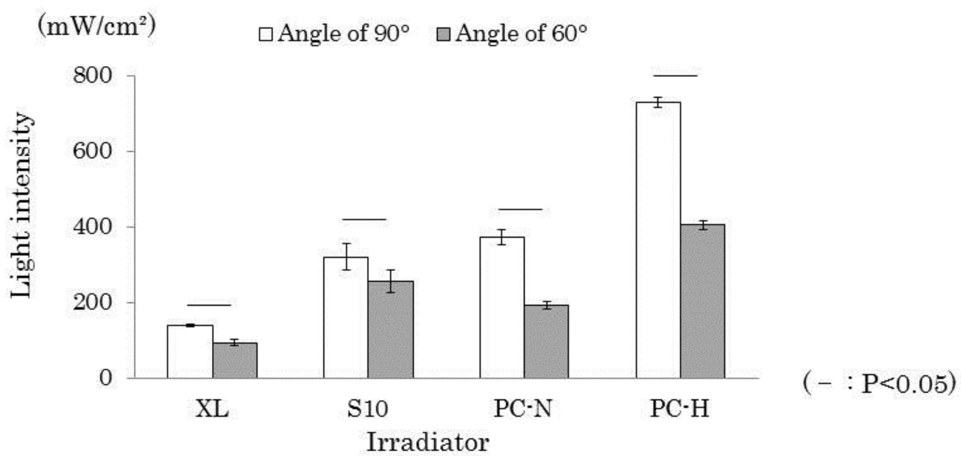

Fig. 4 The light intensity by irradiation angle

Using any irradiator, when light was emitted at 60° to the occlusal surface, the light intensity significantly decreased compared with that at 90°.

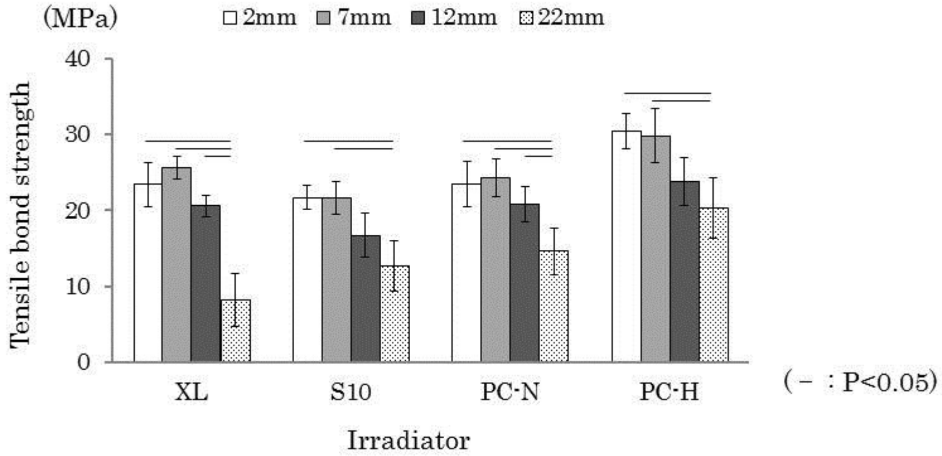

Fig. 5 Influence of irradiation distance on tensile bond strength

Using any irradiator, the tensile bond decreased as the irradiation distance increased. The tensile bond strength significantly decreased when the irradiation distance was 22 mm compared with that at an irradiation distance of 2 mm. No significant difference was noted at an irradiation distance of 7 or 12 mm compared with that at 2 mm.

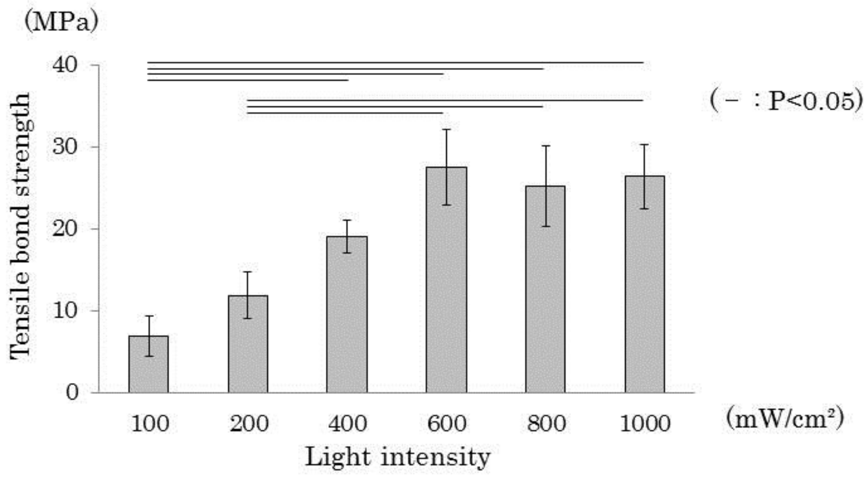

Fig. 6 Influence of light intensity on tensile bond strength

The tensile bond strength increased with the light intensity up to 600 mW/cm^2. The increase was significant at 400, 600, 800, and 1000mW/cm^2 compared with that at 100 mW/cm^2, and at 600, 800, and 1000 mW/cm^2 compared with that at 200 mW/cm^2.

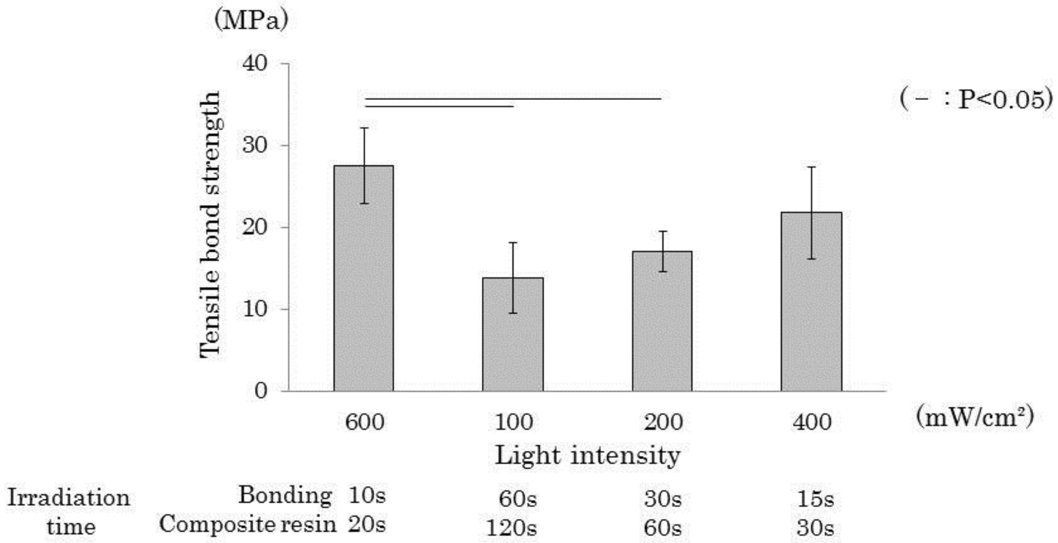

Fig. 7 Influence of the amount of light energy on tensile bonding strength

When the total amount of light energy emitted was specified, compared with the tensile bond strength at 600 mW/cm^2, the strength decreased at the other light intensities, and the decrease was significant at 100 and 200 mW/cm^2 compared with that at 600 mW/cm^2.

Table 1 The irradiators used in this study

Irradiator	Type	Manufacturer	Code
Curing Light XL3000	Halogen	3M ESPE	XL
Elipar S10	LED	3M ESPE	S10
Pencure 2000	LED	MORITA	PC

Table 2 Materials used in this study

	Name	Manufacture	Lot No.	Code
Bonding system	Clearfil Mega Bond	Kuraray Noritake Dental	Primer 8K0047 Bonding 8D0079	MB
Composite resin	Clearfil AP-X (shade：A3)	Kuraray Noritake Dental	01305A	APX

Table 3 Tensile fracture surface of each irradiators

Irradiation distance (mm)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
2	1	2	0	2
7	2	2	0	1
12	2	1	0	2
22	0	0	0	5

XL

Irradiation distance (mm)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
2	0	3	0	2
7	1	1	0	3
12	0	1	0	4
22	0	0	2	3

S10

Irradiation distance (mm)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
2	1	2	0	2
7	3	2	0	0
12	0	3	0	2
22	0	0	2	3

PC-N

Irradiation distance (mm)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
2	3	0	0	2
7	1	1	0	3
12	0	0	0	5
22	0	0	0	5

PC-H

Table 4 Tensile fracture surface of experimental PC

Light intensity (mW/cm^2)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
100	0	0	5	0
200	0	0	5	0
400	1	2	0	2
600	2	3	0	0
800	0	1	3	1
1000	2	3	0	0

Table 5 Tensile fracture surface of experimental PC

Light intensity (mW/cm^2)	Cohesive failure of dentin	Mixture failure	Interfacial fracture	Cohesive failure of resin
100	0	1	0	4
200	1	3	0	1
400	1	4	0	0
600	2	3	0	0

References

1) Tyas MJ, Anusavice KJ, Frencken JE, Mount GJ, Minimal intervention dentistry—a review. FDI commission Project : 1-97, Int Dent J 2000 ; 50 : 1-12.

2) Peters MC, McLean ME. Minimally invasive operative care. Ⅰ. Minimal intervention and concepts for minimally invasive cavity preparations. J Adhes Dent 2001 : 3 : 7-16.

3) Peters MC, McLean ME. Minimally invasive operative care. Ⅱ. Contemporary techniques and materials. J Adhes Dent 2001 : 3 : 17-31.

4) Vanherle G, Smith DC. Posterior composite resin dental restorative materials, 1st ed, Peter Szule Publishing : Amsterdam ; 1985. 455-464,

5) Daido H, Kaneshiro N, Hosoda H. New technique for Class II restoration with visible light-Curing composite resin. Dent Mater J 1987 ; 6 : 218-227.

6) Hembree JH Jr, Microleakage at the gingival margin of Class II composite restorations with glass-ionomer liner. J Prosthet Dent 1989 : 61 : 28-30.

7) Arikawa H, Kanie T, Fujii K, Takahashi H, Ban S, Effect of inhomogeneity of light from light curlng units on the Surface hardness of composite resin, Dent Mater J 2008 : 27 : 21-28.

8) Yoshikawa T, Takatsu T, Hosoda H, Study on marginal integrity of the composite resin restorations —in relation to curing environment and morphological nature of surrounding dentin—. Jpn J Conserv Dent 1989 ; 32 : 639-655. (in Japanese)

9) Ouchi S, Onda K, Hatsuoka Y, Yoshikawa K, Yamamoto K. Study on Experimental LED Curing Light Unit. Jpn J Conserv Dent 2014;57: 19-28.

10) Tashiro K, Matsuzawa N, Ori T, Yamamoto T, Fujibayashi K, Momoi Y. Photo Polymerization of New Thin Bonding Agent Using High Power LED. Jpn J Conserv Dent 2004 ; 47 : 642-649. (in Japanese)

11) Matsuzawa N, Ikejima I, Fujibayashi K, Momoi Y. The Adhesive Strength to Dentin of Resin Composites with LED Curing Unit. Jpn J Conserv Dent 2004 ; 47 : 253-260. (in Japanese)

12) Fujibayashi K, Ishimaru K, Kohno A. Newly Developed Light-activation Unit using Blue Light-emitting Diodes - Part 1 : A Fundamental Study -. Jpn J Conserv Dent 1996 ; 39 : 180-188.

13) Takahashi N, Fujibayashi K, Ishimaru K, Kohno A. Newly Developed Light-activation Unit using Blue Light-emitting Diodes : Part 2. Effects of Spectral distribution of SQW-LED on polymerization of Resin composite. Jpn J Conserv Dent 1998 ; 49 : 509-515. (in Japanese)

14) Matsuzawa N, Sanpei T, Hanabusa M, Fujibayashi K, Takamizu M, Kohno A. Change of micro-hardness evaluated for a resin composite polymerized using Xenon activating unit. Jpn J Conserv Dent 2000 ; 43, 89, B-23 . (in Japanese)

15) Takahashi T, Komori S, Hamada M, Shibuya R, Matsuzawa N, Fujibayashi K, Takamizu M. A Study of a Newly Developed Light-activation Unit Using Blue Light-emitting Diodes : Part 4. Interchangeability with a Halogen Light-culing Unit. Jpn J Conserv Dent 2002 ; 45 : 1067-1074. (in Japanese)

16) Ouchi S, Hatsuoka Y, Onda K, Nomura Y, Yokota K, Matsuda T, Tsutani K, Hatashita Y, Yoshikawa K, Yamamoto K. Study on Newly-developed High-power LED Curing Light Unit : Influence on Bonding Resin. Jpn J Conserv Dent 2013;56:44-149. (in Japanese)

17) Fujii S. Study on marginal leakage of visible light-cured composite restoration, Jpn J Conserv Dent1988 ; 31 : 1043-1061. (in Japanese)

18) Darbyshire PA, Messer LB, Douglass WH. Microleakage in classⅢ composite restoration bonded to dentin using thermal and load cycling. J Dent Res 1988 ; 67 : 585-587.

19) Hotta M, Yamamoto K, Nishio M. Kondou M, Kimura K. Tensile strength of bonding agents. Jpn J Conserv Dent 1989 : 32 : 916-919. (in Japanese)

20) Hotta M, Kondoh K, Kamemizu H. Effect of primers on bonding agent polymerization. J Oral Rehabil 1998：25：792-799.
21) Miyazaki M, Fujii S, Sato H, Sato T, Ando S, Onose H, A Study on visible light curing unit －Curing characteristics of light-Cured resins polymerized with LED curing units－. Adhes Dent 2002；20：165-174. (in Japanese)
22) Cwewkja E, Cakirer B. Effect of short curing times with a high-intensity light-irradiating diode or high-power halogen on shear bond strength of metal brackets before and after thermocycling. Angle Orthod 2011；81：510-516.
23) Shinkai K, Suzuki S, Katoh Y. Effect of light intensity or adhesives on shear bond strength to dentin. Dent Mater J 2008：27：660-665.
24) Tsubota K, Yamamoto A, Uekusa S, Rikuta A, Hinoura K, Iwauchi N, Ando S, Miyazaki M. Influence of light intensity on dentin bond strengths of single-step self-etch systems. Adhes Dent 2006；24：33-38.
25) Seki N, Nakajima M, Kishikawa R, Hosaka K, Foxton RM, Tagami J. The influence of light intensities irradiated directly and indirectly through resin composite to self-etch adhesives on dentin bonding. Dent Mater J 2011：30：315-322.
26) Davidson CL, de Gee AJ. Light-curing units, polymerization, and clinical implications. J Adhes Dent. 2000；2：167-73.
27) Operative dentistry 21. 4th ed. Nagasue Shoten: Kyoto; 2011. 154. (in Japanese)

照射エネルギーが接着強さに与える影響

野津繁生，松田有之，岩田有弘，吉川一志，山本一世

大阪歯科大学歯科保存学講座

抄録

【目的】

近年，MI の概念に基づいた治療が一般的になり，大臼歯部の修復においてもⅡ級窩洞で CR 修復が広く行われるようになっている．しかし大臼歯のⅡ級窩洞では，MI による歯質削除量を極力抑えた幅の狭い窩洞が形成されると同時に，セクショナルマトリックスなどの歯の解剖学形態に合わせた隔壁が装着されるため，窩洞最深部の歯肉側壁まで重合のための光が届きにくい環境となる．そこで本研究では，ハロゲン型照射器と発光ダイオード（以後，LED）照射器を用いて，光照射時の照射距離および光強度を規定して引張接着強さを測定することで，照射器の照射エネルギーが CR 修復時の接着強さに与える影響について検討を行った．

【材料および方法】

光照射器にはハロゲン型光射器として Curing Light XL3000（3M ESPE，XL）を，LED 型光射器として Elipar™ S10（3M ESPE, S10）と PENCURE 2000（モリタ製作所，PC）を使用した．各光照射器の照射距離を 2mm，7mm，12mm，22mm に規定し，光強度のおよび引張接着強さの測定を行った．また，光照射器の光強度を 100，200，400，600，800，1000mW/cm^{2}に規定し，引張接着強さの測定を行った．

【結果および考察】

照射器の照射角度を咬合面に対して 90°にした場合と比べて，舌側方向から咬合面に対して 60°に光照射した場合，すべての照射器において光強度は有意に低下した．照射器の照射距離を 2，7，12，22mm と増加させると，すべての照射器において光強度は低下し，接着強さも低下した．照射器の光強度を 100，200，400，600mW/cm^{2}と増加させると，接着強さは向上した．照射器の光強度を 100，200，400，600mW/cm^{2}に規定し，それぞれの光エネルギー量を同一となるように照射時間を延長した場合，100，200 mW/cm^{2}の光強度で照射時間を延長しても接着強さは 600mW/cm^{2}に比べて有意に低下した．

このことから，遠距離照射や斜照射によって光照射器の光強度が低下するため，接着強さも低下すると考えられる．

【結論】

大臼歯のⅡ級窩洞へのコンポジット充填の場合，光強度が 400mW/cm^{2}以上の照射器を使用し，各ステップの照射において，照射時間をできる限り長く延長することが望ましいことが示唆された．

キーワード：光強度，照射距離，象牙質接着強さ

責任著書者連絡先：吉川　一志
〒573-1121 大阪府枚方市樟葉花園町 8-1　大阪歯科大学大学院歯学研究科歯科保存学専攻
TEL: 072-864-3077, FAX: 072-864-3177
E-mail: kazushi@cc.osaka-dent.ac.jp