Are We, or Aren't We?

…delivering the energy required to fully cure resin restorations

Presentation by
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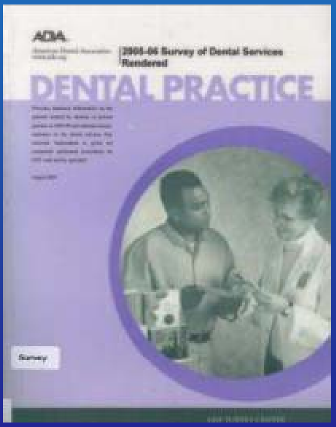
Contains the slides from an AADR keynote presentation, March 2010

Presentation Outline

1. **Resin Use** – Resin is rapidly becoming the restoration material of choice for both patients and dentists.
2. **Concerns** – Resin fillings are not lasting as long as they should.
3. **Limitations** – Current laboratory practices and clinical tools do not provide the insights required.
4. **MARC** – Bridging science and clinical practice.
5. **Findings** – Many dentists and dental assistants are not delivering as much energy as they think and they quickly benefit from training.
6. **Some References**

Resin Composites
DOMINATE THE MARKET

- **130,054 General Dentists in USA**
- **>116 million direct resin restorations**
- **Ave of about 900 / dentist / year**
- **Plus veneers + braces**
- **A curing light was used every time**



Light Curing Units
DETERMINE SUCCESS
…yet are often an afterthought

LCUs in dollars and time:

- **0.05% of the cost of a restoration**

  ($45 billion/yr in restorations, yet LCU sales are only about $20 million/yr)

- **LCUs are used for seconds within a 45 – 60 min procedure**

RESINS ≈ AMALGAN
in terms of longevity

2007 study published in Dental Materials:

Two dentists obtained comparable longevity for amalgam and composite resin restorations.

Opdam, Bronkhorst, Roeters, et al. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater* 2007; 23:2-8.

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RESINS ARE NOT LASTING as long as they could and should

- Recent study of dental records:
  - Amalgam lasts 16 years (ave.)
  - Resin lasts only ***6 years*** (ave.)
- "Unexplained" resin restoration failures concern dentists & patients

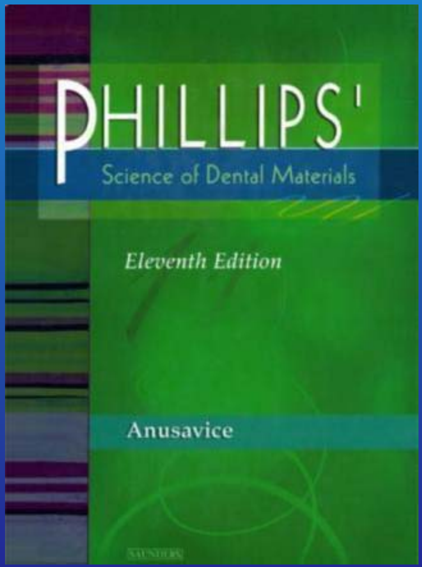
Kovarik RE. **Restoration of posterior teeth in clinical practice: evidence base for choosing amalgam versus composite.** Dent Clin N Am. 2009 Jan.

Simecek JW, Diefenderfer KE, Cohen ME. **An evaluation of replacement rates for posterior resin-based composite and amalgam restorations in U.S. Navy and Marine Corps recruits.** J Am Dent Assoc. 2009 Feb.

Sunnegardh-Gronberg K, van Dijken JW, Funegard U,et al. **Selection of dental materials and longevity of replaced restorations in Public Dental Health clinics in northern Sweden.** J Dent. 2009 Sept.

WHY ARE RESINS NOT LASTING?

Hypothesis: *Resins Are Not Receiving Sufficient Energy at the Appropriate Wavelengths to Adequately Polymerize?*



Chapter 15 Recommends

16 J/cm^2

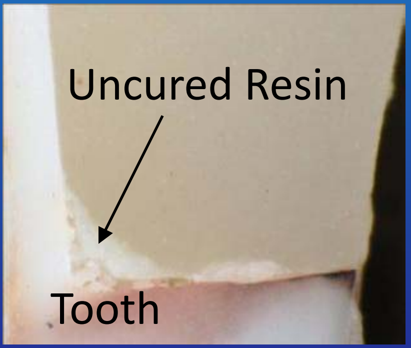
UNDER CURED RESIN

does not deliver
the manufacturer's
intended
physical properties

INADEQUATE CURING

Could be the Cause of:

- Increased wear
- Water sorption and long-term breakdown of the matrix
- Porosity within the matrix
- Increased bacterial colonization
- Secondary caries



Many Curing Lights Do Not Work As Well As They Should

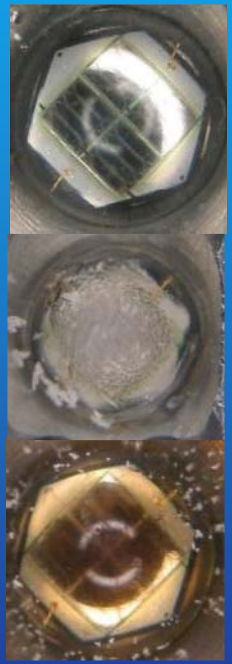
- 214 lights tested in Toronto
  - average 526 mW/cm^2 → 30 sec = 16 J/cm^2
  - 12% < 300 mW/cm^2
- 65 offices and 161 lights in Texas
  - included all types of lights (QTH,PAC,LED)
  - 16.6% less than 249 mW/cm^2 → 64 sec = 16 J/cm^2

El-Mowafy O, El-Badrawy W, Lewis DW, et al. Efficacy of halogen photopolymerization units in private dental offices in Toronto. J Can Dent Assoc. 2005
Barghi & Fischer. Revisiting the intensity output of curing lights in private dental offices. Compend Contin Educ Dent. 2007

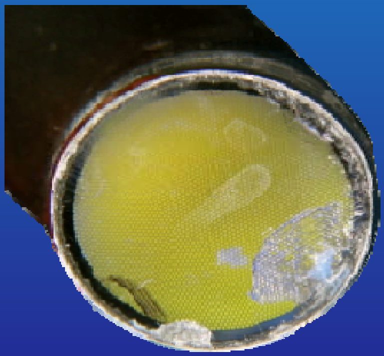
Output Changes Over Time

Bulbs Degrade

LEDs Degrade



Light Guides Dirty
Or Damaged



Underperforming LCUs
Have At Least Three Problems:

To deliver the required energy:

1. An underperforming LCU would need to be ***used for longer*** than the manufacturer's recommended times to deliver the required energy
2. The dentist has ***no way of knowing*** how much longer
3. The dentist cannot arbitrarily increase curing times because LCUs can deliver the ***same amount of heat*** even when irradiance levels are lower

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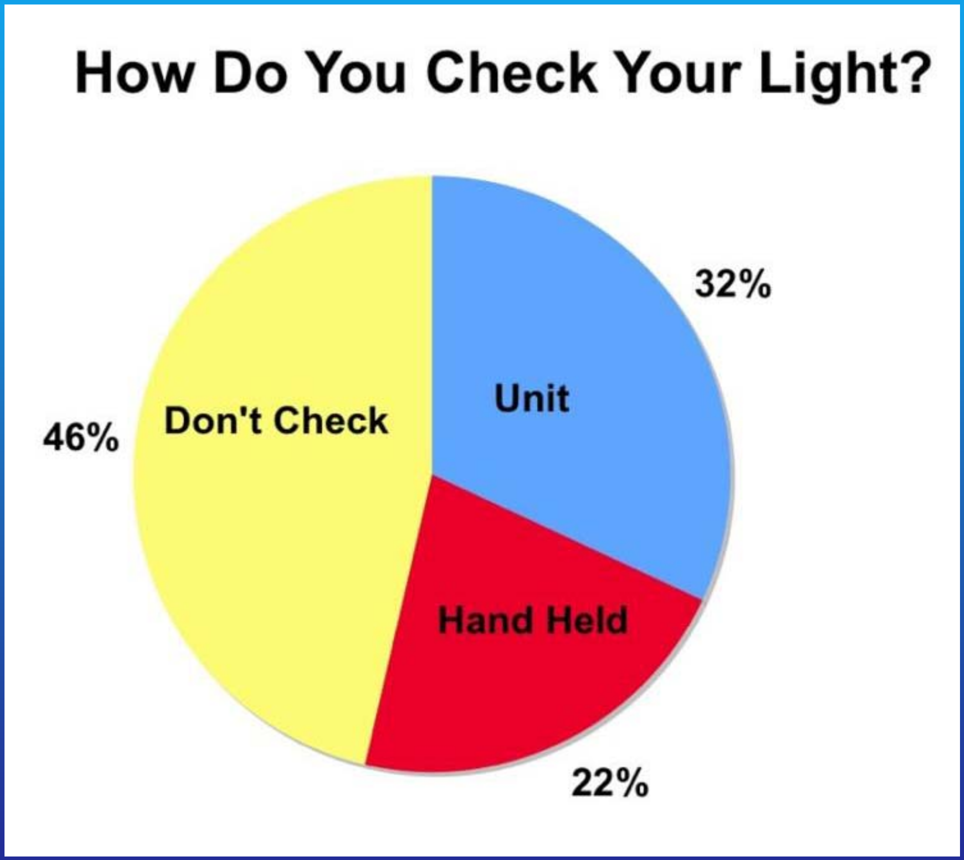
DO YOU CHECK YOUR LIGHT? Results 247 Dentists: 2006



How Can A Dentist Know What Their Light Is Delivering Clinically?

Dental radiometers are inaccurate

– only indicate if the light is turned on

1905 mW/cm^2

600 mW/cm^2

How Much Energy
Should be Delivered?

Many manufacturer instructions rely on dentists having:

- Accurate radiometer readings
- New lights that have not degraded with time
- “Perfect” technique with the light a 90° at 0 mm with no movement

Most resin manufacturers make **Time and Irradiance** recommendations

In any case incremental placement (in 2 mm layers or less) is recommended to minimize polymerization shrinkage. Light cure each increment according to the below table[4]:

	≥ 500 mW/cm²	≥ 800 mW/cm²
Ceram·X mono shades (M1 to M7)	20 sec	20 sec
Ceram·X duo dentin shades (D1 to D4 and DB)	40 sec	30 sec
Ceram·X duo enamel shades (E1 to E3)	10 sec	10 sec

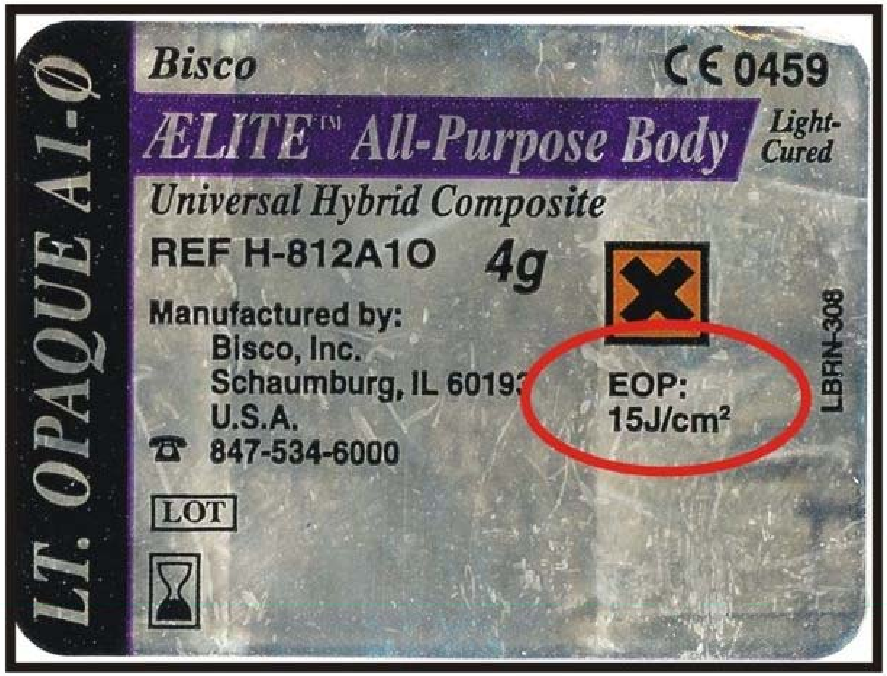
= A Range of **5-24 J/cm²**

(depending on the selected shade)

…however…

dentists have no way of knowing how much energy is actually delivered

SOME TELL YOU the total energy required



Requires 15 J/cm^2 to be fully cured

Regardless…

dentists still have no way of knowing how much energy is actually delivered

This is because there are

Four Determinants Of Intraoral Energy Delivery

1. Curing Light
2. Operator Technique
3. Type of Restoration
4. Resin Energy Requirement

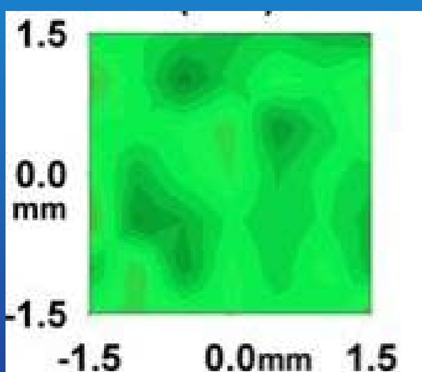
Laboratory Tests CANNOT QUANTIFY ENERGY DELIVERED In A Clinical Setting

- not conducted in a simulated clinical environment
- distance, angle, movement and light design all dramatically affect the energy delivered

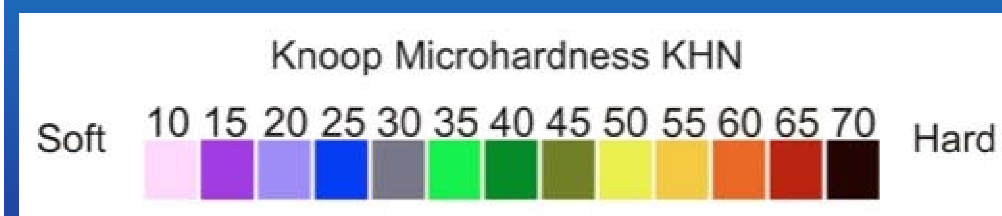
CLINICIANS HAVE NO WAY OF KNOWING IF THE RESIN IS ADEQUATELY CURED

Top surface hardness is not an indicator

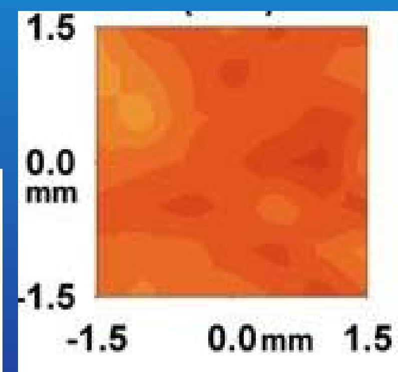
BOTTOM: SOFT



Knoop hardness map



TOP: HARD



Dentists simply need to know how long to use their curing light for!

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MARC

Measurement of accuracy when resin curing

MARC: SPECTROMETER BASED SYSTEM THAT CALCULATES USEFUL ENERGY RECEIVED BY A RESTORATION

Typodont head with probes in different teeth measure light received

WHO NEEDS MARC?

- Dental, Hygiene and Dental Assisting Schools
- Continuing Education Course Providers
- Examining Boards
- Manufacturers of Curing Lights and Resin

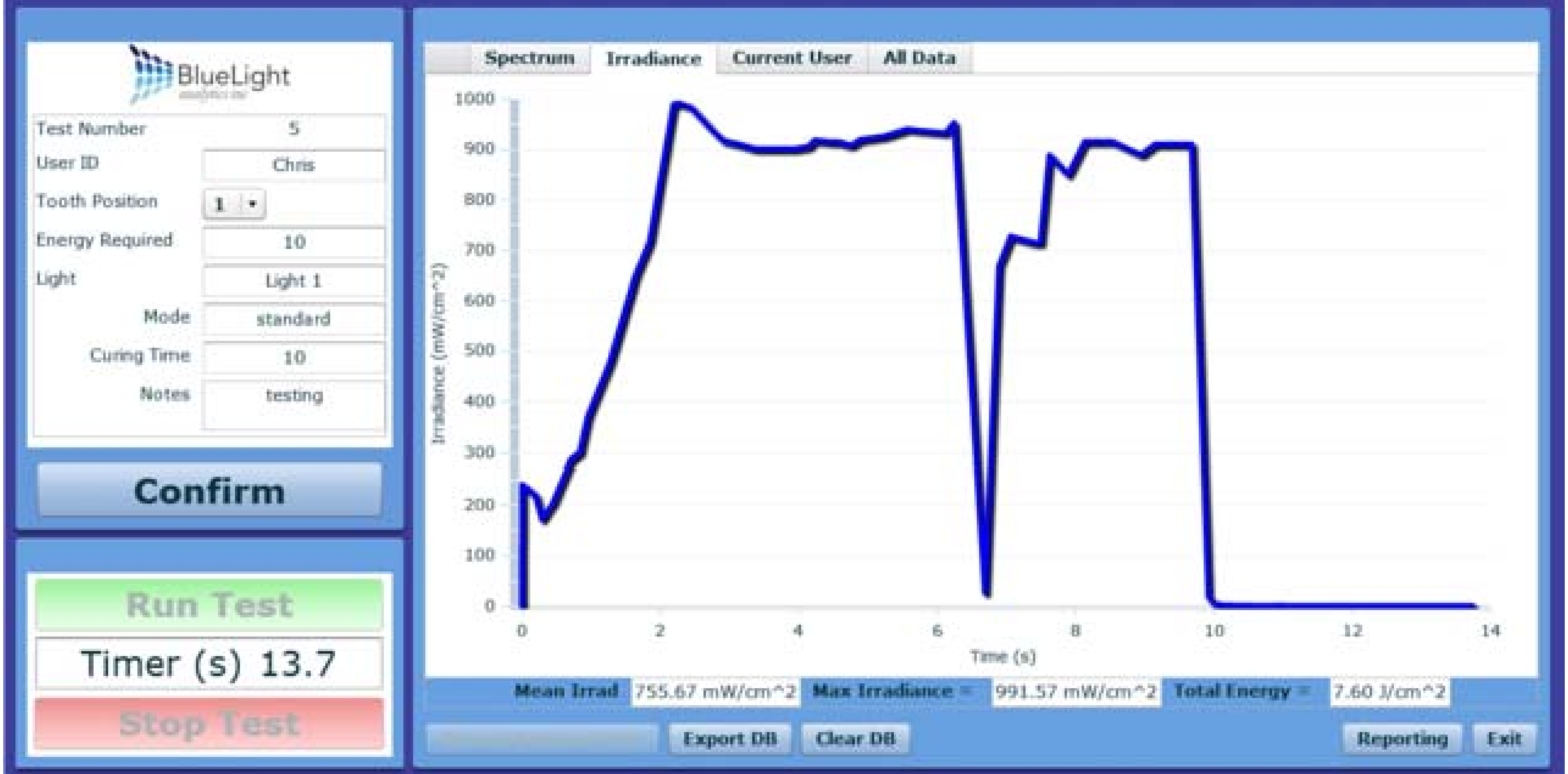
MARC CAN BE USED TO TEACH HOW TO CURE

MARC QUICKLY SHOWS HOW A POWERFUL LIGHT CAN BE USED IMPROPERLY



Poor technique can eliminate the benefits of a powerful light

MARC INTERFACE



MARC CAN BE USED TO EVALUATE CLINICAL PERFORMANCE

Before Instruction

- NOT looking, NOT stabilizing
- NOT wearing eye protection!

After Instruction

- Looking, stabilizing,
- Wearing eye protection!

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4. **MARC** – Finally enabling us to bridge science and clinical practice.
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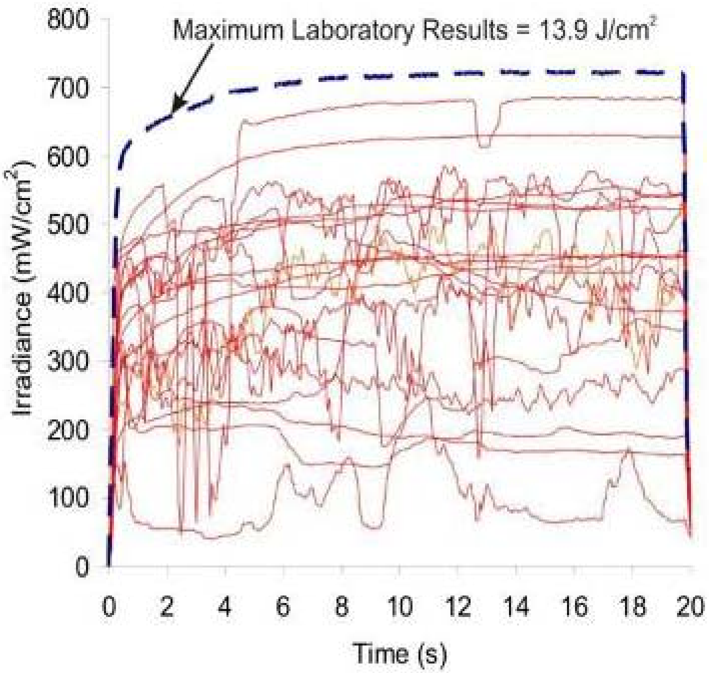
MARC IS A CALIBRATED SYSTEM THAT MEASURES REAL TIME IRRADIANCE DELIVERED

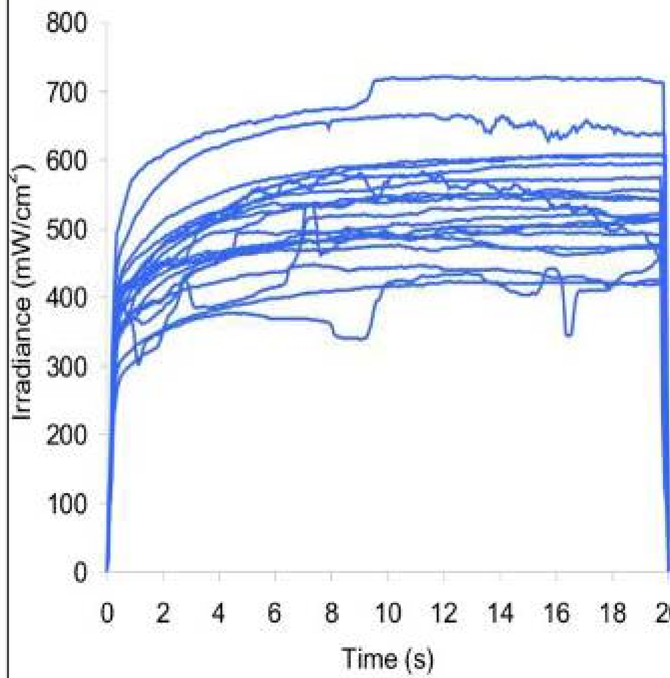
Before



Subjects Delivered a Mean of 7.9 ± 2.7 J/cm²

Subject	Energy Delivered (J/cm²)
1	12.0
2	11.9
3	10.1
4	10.1
5	10.0
6	9.9
7	9.7
8	8.8
9	8.6
10	8.4
11	8.3
12	7.7
13	7.3
14	7.0
15	6.6
16	6.1
17	5.4
18	3.8
19	3.7
20	2.0

After



Subjects Delivered a Mean of 10.1 ± 1.4 J/cm²

Subject	Energy Delivered (J/cm²)
1	13.4
2	12.5
3	11.4
4	11.2
5	10.9
6	10.7
7	10.4
8	10.4
9	10.4
10	10.3
11	9.6
12	9.5
13	9.4
14	9.3
15	9.3
16	9.1
17	9.1
18	8.4
19	7.9
20	7.7

MARC helps to train and 'calibrate' the operators

TESTING OVER 100 DENTISTS WITH MARC

- Using ‘Good’ NEW Lights
- Using Manufacturers Recommended Curing Times
- 10% of the dentists only delivered $<4 J/cm^2$

These Dentists have no way of knowing How Much or How Little Energy they are Delivering

CONCLUSIONS

1. MARC Quantifies a Problem: Many restorations are not receiving the recommended amount of energy
2. MARC can predict how long an operator should use a specific light to deliver the recommended amount of energy
3. MARC can help to establish scientifically accurate and clinically relevant standards in resin curing

To Learn More About MARC, contact

BlueLight analytics inc

Bridging Science and Clinical Practice

www.CuringResin.com

REFERENCES

TOTAL ENERGY CONCEPT

1. Nomoto et al. Effect of light intensity on polymerization of light-cured composite resins. Dent Mater J. 1994;13:198-205.
2. Rueggeberg et al. Effect of light intensity and exposure duration on cure of resin composite. Oper Dent. 1994;19:26-32.
3. Halvorson et al. Energy dependent polymerization of resin-based composite. Dent Mater. 2002;18:463-9.
4. Peutzfeldt et al. Resin composite properties and energy density of light cure. JDR. 2005;84:659-62.

TOTAL ENERGY CONCEPT

ELSEVIER

Dental Materials 18 (2002) 463–469

dental materials

www.elsevier.com/locate/dental

Energy dependent polymerization of resin-based composite

Rolf H. Halvorson[a,*], Robert L. Erickson[b], Carel L. Davidson[c]

[a]3M Dental Products, St. Paul, MN, USA
[b]3M Dental Products, St. Paul, MN, USA
[c]Dept. of Dental Materials Science, Academic Center for Dentistry Amsterdam (ACTA) University of Amsterdam, Amsterdam, The Netherlands

Received 16 January 2001; revised 21 May 2001; accepted 19 June 2001

'The significance of these results is that given the curing profile for a resin based composite, the conversion at any point within the material can be determined for any applied dose'

Total Energy Concept

Resins cured with 12 J/cm²

30s @400 mW/cm²

60s @200 mW/cm²

120s@100 mW/cm²

Fracture toughness and flexural strength were the same

Miyazaki & Oshida, et al. (1996). Dent Mater 12(6): 328-32.

Physical & Chemical Properties Adversely Affected When Less Than Optimal Energy Delivered

1. Caldas DB, et al. Influence of curing tip distance on resin composite knoop hardness number, using three different light curing units. *Oper Dent* 2003; 28(3):315-20.10.
2. Correr AB,et al. Effect of the increase of energy density on knoop hardness of dental composites light-cured by conventional QTH, LED and xenon plasma arc. *Braz Dent J* 2005; 16(3):218-24.
3. Lohbauer U, et al. The effect of different light-curing units on fatigue behavior and degree of conversion of a resin composite. *Dent Mater* 2005; 21(7):608-15.
4. Xu X, et al. Shear bond strength with increasing light-guide distance from dentin. *J Esthet Restor Dent* 2006; 18:19-27
5. Kim S et al. Curing effectiveness of a light emitting diode on dentin bonding agents. *J BMR B Appl Biomater* 2006; 77(1):164-70.
6. Ferracane JL, et al. Wear and marginal breakdown of composites with various degrees of cure. *J Dent Res* 1997; 76(8):1508-16.
7. St-Georges AJ, et al. Curing light intensity effects on wear resistance of two resin composites. *Oper Dent* 2002; 27(4):410-7.
8. Vandewalle KS, et al. Effect of energy density on properties and marginal integrity of posterior resin composite restorations. *Dent Mater* 2004; 20(1):96-106.

Biocompatibility Adversely Affected When Less Than Optimal Energy Delivered

1. Moin Jan C et al. The relationship between leachability of polymerization initiator and degree of conversion of visible light-cured resin. *J Biomed Mater Res* 2001; 58(1):42-6.

2. de Souza Costa CA, et al.. Effects of light-curing time on the cytotoxicity of a restorative resin composite applied to an immortalized odontoblast-cell line. *Oper Dent* 2003; 28(4):365-70.

3. Franz A, et al. Cytotoxic effects of packable and nonpackable dental composites. *Dent Mater* 2003; 19(5):382-92.

4. Knezevic A,et al . Cytotoxicity of composite materials polymerized with LED curing units. *Oper Dent* 2008; 33(1):23-30.

5. Jontell M,et al.. Effects of unpolymerized resin components on the function of accessory cells derived from the rat incisor pulp. *J Dent Res* 1995; 74(5):1162-7.

TEMPERATURE RISE WITHIN THE PULP DURING RESIN POLYMERISATION USING THREE LIGHT SOURCES

Temperature Rise °C

10 secs	QTH 500mW/cm ^{2}	LED 1100mW/cm ^{2}	LED 1100mW/cm ^{2}
Max	**4.9**	**7.1**	**6.4**

Santini A, Open Dent J. 2008;2:137-41.

NO CURRENT CLINICAL OPTIONS

Clinicians cannot arbitrarily increase curing times beyond the manufacturer's recommendations

DO NOT JUST DOUBLE THE CURING TIME

LONGEVITY OF POSTERIOR COMPOSITES

Thirteen of 24 studies were terminated after 3 year indicating that favourable results for composite materials are frequently based on short-term results

Brunthaler et al. Longevity of direct resin composite restorations in posterior teeth. Clin Oral Investig 2003:63-70.

Longevity of Posterior Composites

Longevity of composites in private practice ~35% of academic clinical trials

Bayne et al. (1991) Clinical longevity of ten posterior composite materials based on wear. J Dent Res 70:340 (abstract)

DENTAL RADIOMETERS

- **Dental radiometers are NOT accurate and should not be used in dental research**
- **Useful tools for monitoring the output from a curing unit**
- **Diameter of light guide affects the accuracy of the radiometers**

Slide 0

- **Hansen and Asmussen (1993). Reliability of three dental radiometers. Scand J Dent Res 101: 115-9.**
- **Leonard et al. (1999). Effect of curing-tip diameter on the accuracy of dental radiometers. Oper Dent 24: 31-7.**
- **Roberts et al. (2006). Accuracy of LED and halogen radiometers using different light sources. J Esthet Restor Dent 18: 214-22.**

2010 AADR ABSTRACTS

722 Reproducibility of an Intra-Oral Light Energy Measurement Device

Friday, March 5, 2010: 10:45 a.m. - 12:15 p.m.
Location: Room 150B (Walter E. Washington Convention Center)

C. LEE, R.B. PRICE, and C.M. FELIX, Dalhousie University, Halifax, NS, Canada

Objectives: This study determined the accuracy and reproducibility of a device designed to measure the irradiance delivered to a tooth and to then calculate the total amount of energy delivered during light curing.

Methods: MARC (Measurement of Accuracy when Resin Curing) consists of a dental mannequin head with light sensors located in multiple positions in the teeth to measure the light delivered to a restoration during light curing. These sensors are connected to a fiberoptic spectroradiometer (USB 4000, Ocean Optics) and MARC includes the necessary software to process the information collected by those sensors and presents the data in a manner that can effectively guide research, product development, clinical training and product demonstration. To determine the accuracy and reproducibility of MARC, the irradiance from one curing light (Bluephase 16i, Ivoclar-Vivadent) was measured fifteen times over a period of three days. Between each recording, the entire set-up was disassembled and recalibrated using two different NIST referenced calibration sources (Cal 1 and Cal 2), and then reassembled. The 10 irradiance values obtained using MARC were then compared to 5 irradiance values measured under controlled laboratory conditions using a NIST referenced spectroradiometer (USB 4000, Ocean Optics). The irradiances values obtained from the curing light were compared with ANOVA and Fisher's PLSD α=0.05.

Results: There was no significant difference between the different recordings made using MARC in the mannequin head. Although the values obtained from MARC were significantly greater than those obtained in the laboratory, the difference was less than 3% (43mW/cm^2) and can be attributed to the reflections from the tooth preparation walls.

Fisher's PLSD for IRRADIANCE				
	Mean Difference	Critical Difference	P-Value	Significant Difference
Laboratory Measurement vs. MARC Cal 1	-33.4	13.565	0.0002	Yes
Laboratory Measurement vs. MARC Cal 2	-42.6	13.565	<.0001	Yes
MARC Cal 1 vs. MARC Cal 2	-9.2	13.565	0.1652	No

Conclusions: MARC can accurately and reproducibly record the irradiance delivered by a curing light to a tooth that is located in a mannequin head.

723 Accuracy of an Energy Measurement System To Measure Curing Lights

Friday, March 5, 2010: 10:45 a.m. - 12:15 p.m.
Location: Room 150B (Walter E. Washington Convention Center)

R.B. PRICE, and C.M. FELIX, Dalhousie University, Halifax, NS, Canada

Objectives: This study determines the accuracy of a device that measures the irradiance and calculates the amount of light energy/unit area delivered to a tooth in a mannequin head.

Methods: MARC (Measurement of Accuracy when Resin Curing) is a device that has been developed to measure the irradiance delivered to a tooth and calculate the total amount of light energy delivered to a restoration. MARC consists of a dental mannequin head with detectors embedded in multiple positions in teeth. To determine the accuracy of MARC, four types of commercial curing lights were tested: A Plasma Arc (PAC), Quartz-tungsten-halogen (QTH), single peak LED, and polywave LED curing lights were all used for 10 seconds and their light outputs measured. Each light was measured five times in random order using MARC in a maxillary molar Class I preparation in the mannequin head, and five times using a NIST referenced fiberoptic spectroradiometer system on the laboratory bench. The results were compared with ANOVA and Fisher's PLSD α=0.05.

Results: ANOVA showed that for these four lights there was no significant difference between the irradiance measurements made by MARC or on the laboratory bench.

ANOVA Table for Irradiance							
	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Round	9	1.255	0.139	0.005	>.9999	0.044	0.051
Residual	30	855.842	28.528				

There was a significant different between all the lights, with the PAC light delivering the greatest energy/unit area in 10 seconds: PAC 22.9±0.4 J/cm^2, Single peak LED 14.4±0.4 J/cm^2, Polywave LED 13.7±0.6 J/cm^2, and QTH 10.4±0.2 J/cm^2.

Conclusions: The irradiance and total energy/unit area recorded by MARC from these four classes of curing lights was not significantly different from a NIST referenced laboratory based measurement.

This research was supported by NSERC Discovery Grant # 298326, Springboard Atlantic and Dalhousie University.

M. MCLEOD, R.B. PRICE, and C.M. FELIX, Dalhousie University, Halifax, NS, Canada

Objectives: This study measured the total energy delivered by four LED-curing lights to tooth preparations in a dental mannequin.

Methods: A device (MARC) has been developed to measure the irradiance delivered from a curing light to a tooth in a mannequin head. MARC software calculates the amount of light energy delivered to the sensors in the teeth. After obtaining appropriate Ethics Committee approval, 10 final year dental students and 10 dentists light cured Class I and Class V simulated restorations in the mannequin head. Lights A, B and C were all used for 10s, light D was used in Plasma mode for 6s. The subjects were told to position the mannequin head as they would for a patient and then to cure the Class I restoration in tooth #1.7 and then the Class V in the #3.7 for the set amount of time. The mouth opening was fixed at 43mm at the incisors and the Class V represented a difficult to reach restoration. The total energy/unit area (J/cm^2) delivered to the restorations by the two groups of operators and four lights were compared with ANOVA and Fisher's PLSD α=0.01.

Results: There was no significant difference between the amounts of energy that dentists and students delivered ($p>0.01$), but there was a wide range in the amount of energy delivered, from 2.6 to 17.4 J/cm^2. There was a significant difference in the energy delivered by the four lights, and between the energy delivered to the Class I and Class V locations ($p<0.01$).

	Class I		Class V	
Curing Light	Mean±S.D. Energy J/cm^2	Range J/cm^2	Mean±S.D. Energy J/cm^2	Range J/cm^2
A	9.9 ± 2.4	3.5-12.3	10.5 ± 2.4	6.1-14.2
B	10.4 ± 2.2	6.4-13.7	7.4 ± 2.5	2.6-11.7
C	12.2 ± 1.8	6.8-14.5	8.4 ± 2.2	3.9-10.8
D	16.4 ± 3.1	8.8-20.4	12.5 ± 4.0	4.4-17.4

Conclusions: Faculty and students delivered equivalent amounts of energy, but there was a wide range in the amount of energy delivered by the 20 operators to the simulated restorations. Less energy was delivered to the difficult to reach the Class V preparation.

This research was supported by Springboard Atlantic and Dalhousie University.

Applied RESEARCH

Quantifying Light Energy Delivered to a Class I Restoration

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Melanie E. McLeod, *BSc, DDS;* **Christopher M. Felix,** *BSc*

Abridged Version

For the full version of this article see www.jcda.ca

Cite this article as: *J Can Dent Assoc* 2010;76:a23

http://www.cda-adc.ca/jcda/vol-76/issue-2/10701.pdf

USING MARC TO SHOW EFFECT OF ANGULATION ON ENERGY DELIVERY