JBR Journal of Interdisciplinary Medicine and Dental Science

Marghalani, J Interdiscipl Med Dent Sci 2015, 3:5
DOI: 10.4172/2376-032X.1000187

Research Article | Open Access

Predicting Transmitted Light Radiant Exposure of Fiber Dowel Cross Sections from Dowel Diameter and Length

Thamer Y Marghalani*

Department of Oral and Maxillofacial Prosthodontics, King Abdulaziz University, Saudi Arabia

Abstract

Purpose: To determine whether dowel diameter and length predict a significant amount of variance in transmitted light radiant exposure (TLRE) while controlling for possible dowel system effects.

Materials and methods: Fiber dowels (FiberKleer sizes 1.25, 1.375, and 1.5; Postec Plus sizes 0, 1, and 3) were used. Ten fiber dowels from each system and size were embedded in C&B temporary resin cylinders. The detector of a radiometer was placed on the apical end of each embedded dowel, and the probe tip of an LED curing light was placed on the coronal end. The light cure machine was activated for 40s. The cylinders were shortened in 1-mm increments and TLRE (in millijoules/centimeter squared) was measured at each increment. TLRE values were analyzed using hierarchical multiple linear regression ($\alpha = 0.001$) with SPSS software.

Results: Dowel system effects explained 0.3% of the variance in TLRE. The total variance explained by the model as a whole was 44% ($p < 0.001$). Dowel diameter and length explained an additional 43.6% of the variance in TLRE after controlling for dowel system effects [R^2 change = 0.436, $p < 0.001$]. The beta value for dowel length (beta = -0.517, $p < 0.001$) was larger than that for dowel diameter (beta = 0.208, $p < 0.001$).

Conclusion: Dowel diameter and length and length can predict TLRE at the apical end of a dowel cross section after controlling for dowel system effects. Dowel system effects did not contribute significantly.

Keywords: Fiber dowel; Transmitted light radiant exposure; Radiometer; Dowel length; Dowel diameter; Regression; Dowel cross section

Introduction

Fiber dowel retention is required for the success of foundation restorations and overlying fixed prostheses [1]. Many factors affect dowel retention, including the depth of cure of the cement used. Light- or dual-cure resin cements are commonly used with fiber dowels [2-4]. Both cement types require light to initiate polymerization, resulting in varying degrees of conversion, or depth of cure, depending on light intensity and degradation along the length of the root canal system [5]. Reports have shown that some dual-cure cements do not reach adequate degrees of conversion in the absence of light [6-8]. The use of translucent dowels has been recommended to improve the degree of conversion in dark areas of the root canal that cannot be reached by curing light [5,9,10].

Several studies have examined the effects of light curing on the degree of resin cement conversion [10-14]. Few reports on light intensity at various locations on different fiber dowels have been published [11,15,16]. A few reports have described the effects of light transmission through dowels on resin cement, such as micro-hardness and degree of conversion, rather than reporting on light intensity or radiant exposure of the fiber dowel [12,13,17-21]. Only two studies have examined light transmission through fiber dowels by measuring light counts with a spectrophotometer or luminous intensity with a digital reader [11,16].

Many factors may affect the intensity, radiant exposure, and energy of light transmitted by translucent dowels [11,12,19]. Irradiance, sometimes confusingly called "intensity", is defined as the radiant flux received by a surface per unit area, measured in Milliwatts per centimeter squared [22]. Radiant exposure, sometimes called "radiant fluence," is the radiant energy received by a surface per unit area, or equivalently the irradiance of a surface integrated over a certain period of irradiation, measured in Millijoules per centimeter squared [23]. In this study, transmitted light radiant exposure (TLRE) refers to the radiant exposure of light transmitted from a certain area of a fiber dowel over a certain period of time.

The objectives of this study were to determine the degree to which dowel diameter and length predict TLRE through the cross section of a fiber dowel, and the amount of variance in TLRE that can be explained by these variables. We examined whether dowel diameter and length predicted a significant amount of variance in TLRE when the possible effects of the dowel system were controlled. The hypothesis was that no linear relationship would be found between TLRE through the dowel cross section and the dowel diameter and length, with and without control for dowel system effects.

Materials and Methods

Two fiber dowel systems were used in this study: FiberKleer (FK, sizes 1.25, 1.375, and 1.5; Pentron Clinical, Orange, CA, USA) and Postec Plus (PT, sizes 0, 1, and 3; Ivoclar Vivadent Inc., Amherst, NY, USA). The FK and PT fiber dowel systems used in this study are glass fiber-reinforced composite systems. Both dowels are plane tapered,

***Corresponding author:** Thamer Y Marghalani, Associate Professor and Consultant, Oral and Maxillofacial Prosthodontics, Division of Fixed Prosthodontics, Faculty of Dentistry, King Abdulaziz University, P. O. Box 11608, Jeddah, Makkah Province 21463, Saudi Arabia, Tel: +966 567438377; E-mail: thamerdr@yahoo.com

Received: October 10, 2015; **Accepted:** October 28, 2015; **Published:** October 30, 2015

Citation: Marghalani TY (2015) Predicting Transmitted Light Radiant Exposure of Fiber Dowel Cross Sections from Dowel Diameter and Length. J Interdiscipl Med Dent Sci 3: 187. doi: 10.4172/2376-032X.1000187

but different lengths and diameters were available for each system. The FK dowel contains a mixture of cured copolymers triethylene glycol dimethacrylate (TEGDMA), and 2, 2-bis [4 (2-hydroxy-3-methacryloxy-propyloxy)-phenyl] propane, also known as bisphenol A glycidyl methacrylate (BisGMA) and 1,6-Hexanediol dimethacrylate (HDDMA), barium borosilicate glasses, and glass fibers. The PT dowel's resin matrix contains a core of urethane ethyl dimethacrylate (UDMA) and TEGDMA, and several additives, such as ytterbium trifluoride, a highly dispersed silicon dioxide. Ten fiber dowels from each system and size were embedded in a temporary resin cylinder made from Systemp. c & b II (Ivoclar vivadent, Schaan, Liechtenstein) to simulate the light passing through a dowel surrounded by shade A2 root dentin (shade A2; Figure 1). Each resin cylinder had a diameter of 10 mm and a length equal to that of the fiber dowel. Before testing specimens, the recorded peak light intensity emanating directly from the curing probe of the LED curing light (LEDition; Ivoclar Vivadent, Schaan, Liechtenstein), measured as a baseline using the radiometer's 8-mm light-guide setting, was 637 mW/cm^2, and total radiant energy was 30.88 J/cm^2 in 40s. The apical end of the embedded dowel was placed on the detector of an ACCU-CAL™ 50-LED radiometer (Dymax Corporation, Torrington, CT, USA), and the probe tip of a LEDition LED curing light was placed on the coronal end of the dowel (Figure 2). The light cure machine was activated for 40s, during which TLRE was measured with the radiometer. The direct light intensity of light cure machine was measured right before each specimen testing to ensure that it stays above 600 mW/cm^2. The cylinders were then cut back progressively in 1-mm increments using a diamond disc saw (Tech-Cut; Allied High Tech Products Inc., Rancho Dominguez, CA USA), and TLRE through the length of the resin block was measured at each increment until dowel length reached 5 mm. The dowel diameter at the apical end of the block was also measured at each increment. TLRE was calculated based on the ratio of actual dowel diameter at the apical end to the 3 mm light guide diameter used in the detector setting, and these values were analyzed using hierarchical multiple linear regression ($\alpha = 0.001$) with SPSS software (version 22.0; IBM Corporation, Armonk, NY, USA). Preliminary analyses were conducted to ensure that the assumptions of normality, linearity, multicollinearity, and homoscedasticity were not violated. Pearson correlation analyses were conducted as a part of the preliminary analyses. Hierarchical multiple linear regression was conducted to assess the ability of dowel diameter and length to predict TLRE through the dowel's cross section at the apical end, after controlling for the effects of the dowel system. The dowel system, entered in step 1 of the analysis to control for its effect. Diameter and length were included in step 2 of the analysis.

Results

Means TLRE of both dowel systems with different diameters and lengths are described in Table 1. Figure 3 shows the mean TLRE for each translucent fiber dowel system, presented for each dowel size and length. The dowel system explained 0.3% of the variance in TLRE [F (1, 838) = 2.803, p = 0.094]. The total variance explained by the model as a whole was 44% [F (3, 836) = 218.72, p < 0.001]. Dowel diameter and length explained an additional 43.6% of the variance in stress, after controlling for dowel system response [R^2 change = 0.436, F (2, 836) change = 325.59, p < 0.001]. In the final model, only dowel diameter and length had significant effects, with a larger beta value for dowel length (beta = -0.517, p < 0.001) than for dowel diameter (beta = 0.208, p < 0.001). Diameter and length were correlated ($r = 0.599$). The unique contributions of dowel diameter and length after the removal or partialling out of any overlap or shared variance were 1.80% and

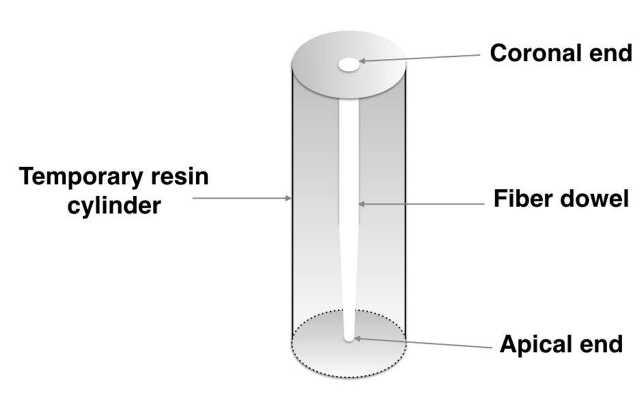

Figure 1: Dowel embedded in the temporary resin as cylinder.

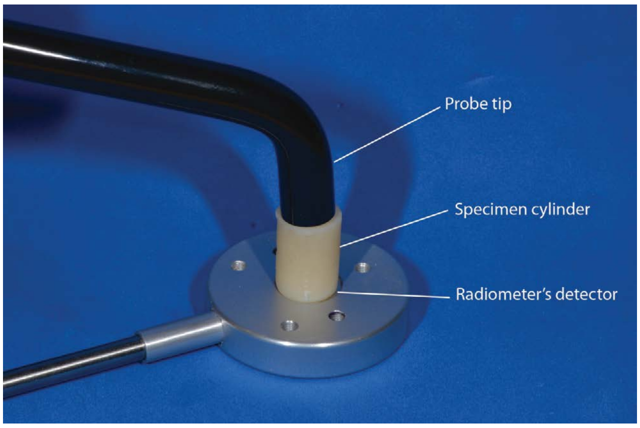

Figure 2: TLRE testing configuration.

11.76%, respectively. When light passed through the fiber dowels, TLRE directly from the light-cure probe tip at the coronal end was reduced. Percentages of TLRE through the dowels ranged from 0% to 9.90% of the TLRE emanating direct from probe tip for FK dowels and from 0% to 14.29% for PT dowels. The TLRE of a dowel's cross section can be calculated using the following multiple regression equation:

$$TLRE\ (dowel\ cross\ section) = 0.208_{diameter} - 0.517_{length} + 596.63$$

Discussion

The study hypothesis was rejected, as dowel diameter and length significantly predicted TLRE through the dowel's cross section at the apical end. Previous researchers have suggested that these additives may influence light transmission because they are white and opaque [13]. These differences, however, did not contribute significantly to TLRE.

Radiant exposure was measured at the apical ends of the cross sections of embedded dowels of different lengths. TLRE depends on light intensity at a certain location and exposure time. The current study showed that the radiant exposure of light passing through a fiber dowel decreased with increased dowel length. Fibers extending from coronal to the apical end of a dowel allowed the transmission of some light, although 85-99% of radiant exposure (energy) was lost. These findings are consistent with reports of the efficacy and predictability of polymerization and degree of conversion of dual-cure cements at apical levels [10,24,25]. Light attenuation through a fiber dowel has been

Dowel System	FiberKleer			PosTec Plus		
Dowel Size	1.25 mm	1.375 mm	1.5 mm	Size 0	Size 1	Size 3
Length	TLRE (mJ/cm²) Mean (SD)	TLRE (mJ/cm²) Mean (SD)	TLRE (mJ/cm²) Mean (SD)	TLRE (mJ/cm²) Mean (SD)	TLRE (mJ/cm²) Mean (SD)	TLRE (mJ/cm²) Mean (SD)
5 mm	3039.08 (21.7)	1666.87 (19.38)	1421.2 (1.78)	839.02 (6.83)	1766.1 (1.07)	4408.4 (3.76)
6 mm	1509.67 (3.86)	935.64 (0.49)	566.7 (1.03)	481.95 (0.93)	1044.1 (0.7)	3431.47 (2.78)
7 mm	1150.4 (15.33)	470.16 (0.56)	405.52 (0.32)	24.93 (8.27)	701.7 (0.86)	1962.67 (2.39)
8 mm	698.05 (28.45)	192.32 (0.49)	250.04 (1.69)	227.7 (0.70)	442.5 (1.41)	1384.93 (1.3)
9 mm	352.44 (7.12)	110.59 (0.23)	116.37 (0.57)	211.12 (1.13)	344.9 (0.7)	934.13 (1.03)
10 mm	150.57 (2.30)	49.13 (0.22)	71.24 (0.22)	157.9 (0.74)	208.1 (0.52)	654.4 (1.81)
11 mm	65.13 (1.00)	23.03 (0.21)	37.75 (0.22)	89.44 (0.68)	202.3 (0.25)	557.59 (0.68)
12 mm	29.13 (0.47)	15.35 (0.17)	23.6 (0.26)	74.45 (1.74)	145.7 (0.63)	396.48 (0.73)
13 mm	2.52 (0.15)	7.95 (0.3)	7.97 (0.16)	57.2 (2.14)	133.8 (0.54)	215.22 (0.79)
14 mm	1.53 (0.15)	3.18 (0.14)	3.81 (0.19)	44.88 (1.52)	853.59 (0.24)	150.19 (0.57)
15 mm	0.7 (0.11)	1.3 (0.13)	2.1 (0.00)	38.79 (1.33)	63.44 (0.37)	102.2 (0.25)
16 mm	0.28 (0.1)	0.40 (0.15)	0.00 (0.00)	29.07 (0.52)	43.76 (0.34)	84.19 (0.50)
17 mm	NA	NA	NA	17.4 (1.04)	27.65 (0.31)	54.77 (0.94)
18 mm	NA	NA	NA	11.09 (0.14)	21.07 (0.26)	31.12 (1.5)
19 mm	NA	NA	NA	4.95 (0.24)	13.98 (0.43)	27.35 (0.19)
20 mm	NA	NA	NA	1.16 (0.21)	12.69 (0.14)	10.8 (0.17)

Table 1: Mean transmitted light radiant exposure of fiber dowels.

proposed to decrease the micro-hardness of resin cements [12].

Radiant exposure is the most important factor in the curing of resin cements, in that cure time is important in allowing the resin cement film to reach an adequate and homogenous degree of conversion along the entire dowel length. The resultant low radiant exposures at long dowels lengths require an increased curing time at the coronal end to compensate for the reduction in radiant exposure in the apical areas of the dowel. Thus, the ability to predict the appropriate amount of radiant exposure for a specific dowel system, diameter, or length is important for the adjustment of resin cement curing time in the clinical setting. We found that the contributions of dowel system factors were insignificant, and lesser than those of dowel diameter and length. Radiant exposure increased with dowel diameter, but decreased with increased dowel length.

Both dowel systems used in this study start coronally from the designated dowel size then taper by a constant apically at a certain length to a small diameter at the apical end. FK dowels start at 9 mm from the apical end to taper apically by 0.05 mm/1 mm from designated diameters of 1.25, 1.375, and 1.5 mm to 0.7, 0.785, and 1.0 mm, respectively. PT dowels sizes 0 and 1 start at 7 mm from the apical end to taper apically by 0.1 mm/1 mm from designated diameters of 1.3, and 1.5 mm to 0.6, and 0.8 mm. And PT dowels size 3 diameter start to taper apically at 10 mm from the apical end from 2.0 mm to 1.0 mm at the apical end. This variation in diameter was taken into account when calculating TLRE from the detector surface before values were entered into the regression analysis. A sharp increase in TLRE was observed for dowels lengths less than 9-10 mm, which may be explained by differences in diameter between tapered and untapered parts of the dowels (Figure 3).

Most dowel lengths embedded in root canals, after considering the recommended 4 to 5 mm apical seal with gutta percha, are 5-8 mm depending on original tooth lengths. As most dowels are cemented clinically at full length, rather than being cut to the desired length before cementation, one would question the role of light transmitted through their apical areas. The most important factor in the light curing procedure for fiber dowels may be the amount of light transmitted in the middle portion of the dowel, when operators use only the cement manufacturer's recommended curing time. As a result, the degree of conversion of the cement around the embedded dowel depends on how well the cement cures chemically, for both light- and dual-cure systems. The direct effect of light curing on excess cement at the coronal opening of the root canal may also contribute to the curing of the cement.

Knowledge of the radiant exposure threshold at which a given resin cement system initiates and/or continues the polymerization process is essential. Values between 21-24 J/cm² ensure homogenous polymerization [26]. Although these recommended values were obtained from the study of 1 to 3 mm thick composite resin restoration, the applicability of this range to thin film resin cements around the dowels is questionable. More studies on the homogeneity of resin cement polymerization in fine thicknesses are required. The regression equation obtained in this study can be used to estimate the required radiant exposure, and thus the amount of time required to ensure an adequate degree of conversion for all cement film around a fiber dowel.

Limitations of the study include, the use of only two glass fiber dowel systems, and one type of light cure machines. Future studies of this nature should include the examination of serrated and parallel fiber dowels, and other light cure machines and dowel systems.

Conclusions

Within the limitations of this study, we can conclude that:

Dowel diameter and length can predict the TLRE at a translucent fiber dowel's apical cross section, after controlling for the effects of the dowel system.

The compositional differences of the FK and PT dowel systems tested in this study did not contribute substantially to TLRE.

References

1. Shillingburg HT, Sather DA, Wilson EL, Cain JR, Mitchell DL (2012) Fundamentals of Fixed Prosthodontics, Fourth Edition.
2. Yearn JA (1985) Factors affecting cure of visible light activated composites. Int Dent J 35: 218-225.
3. Price RB, Derand T, Sedarous M, Andreou P, Loney RW (2000) Effect of distance on the power density from two light guides. J Esthet Dent 12: 320-327.

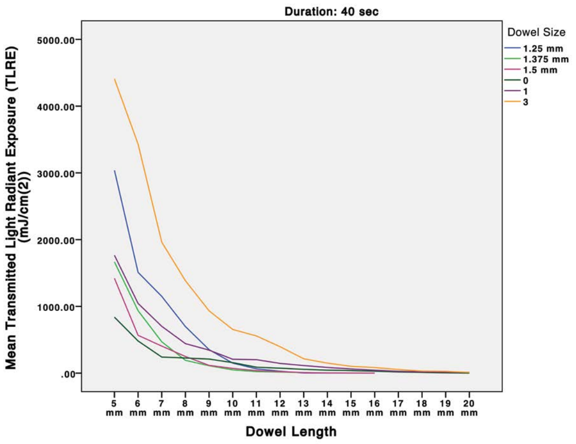

Figure 3: Mean TLRE for each translucent fiber dowel system for each dowel size and length.

4. Ferrari M, Vichi A, Grandini S (2001) Efficacy of different adhesive techniques on bonding to root canal walls: an SEM investigation. Dent Mater 17: 422-429.

5. Yoldas O, Alacam T (2005) Microhardness of composites in simulated root canals cured with light transmitting posts and glass-fiber reinforced composite posts. J Endod 31: 104-106.

6. Caughman WF, Chan DC, Rueggeberg FA (2001) Curing potential of dual-polymerizable resin cements in simulated clinical situations. J Prosthet Dent 86: 101-106.

7. Braga RR, Cesar PF, Gonzaga CC (2002) Mechanical properties of resin cements with different activation modes. J Oral Rehabil 29: 257-262.

8. Kumbuloglu O, Lassila LV, User A, Vallittu PK (2004) A study of the physical and chemical properties of four resin composite luting cements. Int J Prosthodont 17: 357-363.

9. Lui JL (1994) Depth of composite polymerization within simulated root canals using light-transmitting posts. Oper Dent 19: 165-168.

10. Roberts HW, Leonard DL, Vandewalle KS, Cohen ME, Charlton DG (2004) The effect of a translucent post on resin composite depth of cure. Dent Mater 20: 617-622.

11. dos Santos Alves Morgan LF, Peixoto RT, de Castro Albuquerque R, Santos Correa MF, de Abreu Poletto LT, et al. (2008) Light transmission through a translucent fiber post. J Endod 34: 299-302.

12. Galhano GA, de Melo RM, Barbosa SH, Zamboni SC, Bottino MA, et al. (2008) Evaluation of light transmission through translucent and opaque posts. Oper Dent 33: 321-324.

13. Urapepon S (2014) Degree of conversion of resin composite cured by light through a translucent fiber posts. J Adv Prosthodont 6: 194-199.

14. Bahari M, Savadi Oskoee S, Kimyai S, Mohammadi N, Saati Khosroshahi E (2014) Effect of Light Intensity on the Degree of Conversion of Dual-cured Resin Cement at Different Depths with the use of Translucent Fiber Posts. J Dent (Tehran) 11: 248-255.

15. Teixeira EC, Teixeira FB, Piasick JR, Thompson JY (2006) An in vitro assessment of prefabricated fiber post systems. J Am Dent Assoc 137: 1006-1012.

16. Goracci C, Corciolani G, Vichi A, Ferrari M (2008) Light-transmitting ability of marketed fiber posts. J Dent Res 87: 1122-1126.

17. Radovic I, Corciolani G, Magni E, Krstanovic G, Pavlovic V, et al. (2009) Light transmission through fiber post: the effect on adhesion, elastic modulus and hardness of dual-cure resin cement. Dent Mater 25: 837-844.

18. Dogar A, Altintas SC, Kavlak S, Guner A (2012) Determining the influence of fibre post light transmission on polymerization depth and viscoelastic behaviour of dual-cured resin cement. Int Endod J 45: 1135-1140.

19. Taneja S, Kumari M, Gupta A (2013) Evaluation of light transmission through different esthetic posts and its influence on the degree of polymerization of a dual cure resin cement. J Conserv Dent 16: 32-35.

20. Khabeer A, Whitworth J, Rolland S (2015) Polymerization kinetics of resin cements after light activation through fibre posts: an in vitro study. Int Endod J 48: 261-267.

21. Kim YK, Kim SK, Kim KH, Kwon TY (2009) Degree of conversion of dual-cured resin cement light-cured through three fibre posts within human root canals: an ex vivo study. Int Endod J 42: 667-674.

22. Tilley RJD (2011) Colour and the optical properties of materials : an exploration of the relationship between light, the optical properties of materials and colour. (2nd edn), Wiley, Hoboken, N.J.

23. McNaugth AD, Wilkinson A, International Union of Pure and Applied Chemistry (1997): Compendium of chemical terminology : IUPAC recommendations. (2nd edn), Blackwell Science, Oxford England; Malden, MA, USA.

24. Faria e Silva AL, Casselli DS, Ambrosano GM, Martins LR (2007) Effect of the adhesive application mode and fiber post translucency on the push-out bond strength to dentin. J Endod 33: 1078-1081.

25. Goracci C, Grandini S, Bossu M, Bertelli E, Ferrari M (2007) Laboratory assessment of the retentive potential of adhesive posts: a review. J Dent 35: 827-835.

26. Rueggeberg FA, Caughman WF, Curtis JW Jr (1994) Effect of light intensity and exposure duration on cure of resin composite. Oper Dent 19: 26-32.

Citation: Marghalani TY (2015) Predicting Transmitted Light Radiant Exposure of Fiber Dowel Cross Sections from Dowel Diameter and Length. J Interdiscipl Med Dent Sci 3: 187. doi: 10.4172/2376-032X.1000187