DETECTION OF ACOUSTIC EMISSION DURING DENTAL COMPOSITE RESTORATION

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Introduction

Dental composites exhibit the inherent problem of volumetric shrinkage during the polymerization process. This polymerization shrinkage disrupts the marginal seal between the composite and the tooth structure. Various experiments such as SEM[1], dye penetration test[2] have been performed for evaluating the marginal integration by observing the composite resin-tooth interface. In this study, an AE technique was applied to dental composite restoration. AE signals are detected in real-time for analyzing the marginal disintegration process of the restoration.

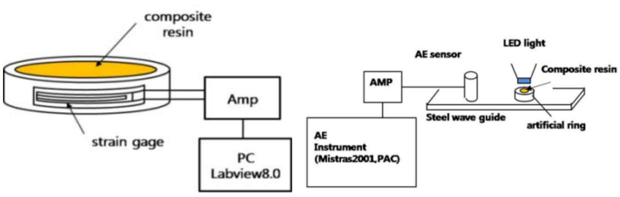
Experimental

Circumferential stress measurement

For the measurement of polymerization contraction in composite resins using electrical resistance strain gauge[3], a penetrated ring type substrate (inner diameter 6mm, outer diameter 8mm, height 2mm) was prepared. Two substrate materials were adopted: stainless steel (SUS304), optically transparent polymethyl methacrylate(PMMA) polymer. An electrical resistance strain gauge (KFG-1-120-C1-11L1M2R, 1mm in gauge length, Kyowa, Japan) was attached to the outer lateral surface of the ring with cyanoacrylate bonding agent. Length direction of the strain gauge conformed to the circumference of the ring as illustrated in Fig.1(a). The ring substrate was washed with ethyl alcohol to condition the surface. A dentine bonding agent (Clearfil S3, Kuraray, Japan) and then a composite resin (Clearfil AP-X, Kuraray, Japan) were applied onto the inner surface of the ring following manufacturer's instruction. The composite resin was cured for 20 sec with the above LED light source. Strain (ε) measurement was recorded in real time during the light exposure period and continued for a period of 180 minutes until a full equilibrium was reached in the polymerization contraction.

Acoustic emission measurement

For the acoustic emission (AE) measurement during the composite restoration, a non-penetrated ring type substrate (inner diameter 6mm, outer diameter 8mm, depth 2mm, height 3mm) was prepared. Three substrate materials of stainless steel, PMMA and human tooth were adopted as the above. For comparison of bonding quality, rings without adhesive coating as well as rings with adhesive coating, but not exposed by the LED light, were also prepared. Fig.1(b) shows a schematic of the AE measurement. The specimen was mounted on the wave guide steel plate using specially designed mechanical fixture. An AE sensor (micro30, Physical Acoustic Corp.) with a detectable frequency range of 100–600 kHz, a peak sensitivity at 250 kHz and a close distance of 15mm from the ring specimen was also mounted on the steel plate. The vacuum grease was also coupled between the sensor and the plate. AE measurement conditions of a pre-amp of 40 dB, a threshold level of 25 dB and a sampling rate of 4 MHz were adopted. After the test, each stored AE signal was analyzed through a fast Fourier transform(FFT). From this AE test, the acoustic emission hit event counts, the amplitude distribution and the time-amplitude signals were measured.



(a) (b)

Fig.1 Schematic of the strain measurement(a) and the acoustic emission measurement(b).

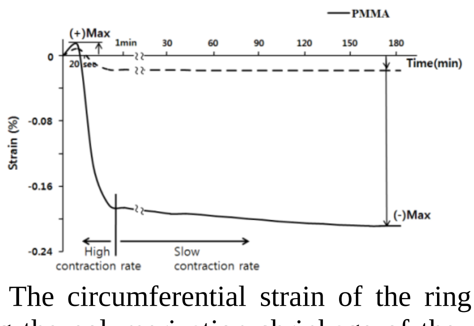


Fig.2 The circumferential strain of the ring substrate during the polymerization shrinkage of the composite resin.

Results and Discussion

Circumferential stress analysis

The typical circumferential strain behaviors of the penetrated ring filled with the composite resin during the curing as recorded in real time are shown in Fig.2. The specimen rings in this figure were in a state surface-coated with the bonding agent and treated by the LED light exposure prior to the composite restoration. The maximum compressive (-) strain of the PMMA ring was about 12.1 times larger than that of the steel ring. The maximum compressive (-) stress of the steel ring was about 5.8 times higher than that of the PMMA ring. The adhesive bonding treated by the light exposure affected a substantial increase in the maximum compressive stress.

Acoustic emission analysis

Fig.3 shows a typical AE signal monitored from the human dentin restoration specimen which was a blast type having only a frequency band of 100-200kHz. This type of AE signal occupied beyond 86% of the total hit events detected for 180minutes. The remaining events were also a blast type having two separate frequency bands containing an additional 240-300kHz band. Bad bonding states were indicated by many hit events in the initial curing period of 1 minute with high contraction rate. The quantity of hit events for the human molar dentin specimen was much less than that for the steel ring specimen but more than that for the PMMA ring specimen. The better the bonding state, the less the AE hit events(Table 1). Their peak amplitudes supported such a distribution characteristic in that weak emissions were generated in the initial curing period while most strong emissions were in the post period. This distribution behavior of hit events as detected over the curing time was much distinguished by the bad bonding(Fig. 4). Cracks were identified in the marginal region where the number of cracks for the steel ring specimen appeared more than that for the PMMA and/or the human molar dentin specimens (Figs.5). Such cracks may arise with emitting some elastic waves, which can be monitored for an on-line analysis of the marginal disintegration process.

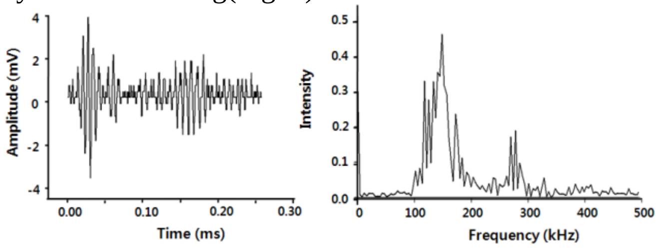


Fig.3 AE signals from polymerization shrinkage

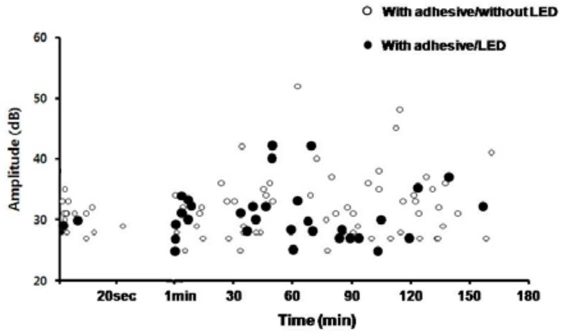


Fig.4 AE peak amplitude distribution versus time in dental restoration of the human molar dentin substrate

Table 1 AE hit events from various substrate specimens.

Materials	Adhesive condition	n	AE hit event (mean±S.E)	P-value
Stainless Steel	Without adhesive	10	20.60±2.41	0.021
	With adhesive/Without LED	6	13.17±1.63	
	With adhesive/LED	5	12.00±1.28	
PMMA	Without adhesive	9	4.33±0.29	0.013
	With adhesive/Without LED	7	3.57±0.60	
	With adhesive/LED	7	2.43±0.16	
Human Tooth	Without adhesive	5	14.20±3.48	0.029
	With adhesive/Without LED	6	14.33±1.50	
	With adhesive/LED	4	6.75±0.85	

(a) (b)

Fig. 5 SEM taken from the marginal gap formation region of composite resin-stainless steel(a) and human molar ring interface.

Conclusions

The AE technique was applied to the dental composite restoration which was subjected to light curing. It was ascertained that AE happened during the polymerization shrinkage of composite resin. The AE characteristics were comparable to the deteriorated strain behaviors, which could be used for a nondestructive characterization of the marginal disintegrative fracture of the dental restoration.

Acknowledgement

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