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Three-dimensional evaluation of gap formation of cervical restorations

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Summary *Objectives*. In some studies gap formation has been evaluated in just one section of the restorative. This in vitro study aimed to design a quantitative three-dimensional method for evaluation of the contraction gap in restoratives.

Methods. Cervical cavities were prepared on buccal, palatal or lingual surfaces in human extracted molars and were then filled with resin composites. Specimens were reduced every 100 μm in a direction parallel to the tooth axis, and perpendicular to the cavity floor from one proximal side to the other. The sequence of reducing the sections by 100 μm, image taking (250×) and observation of these images (maximal 2500×) were repeated. Three-dimensional images of the contraction gap were made using analytical software and the proportions of the interface with gap formation calculated.

Results. The mean proportions of the interface with gap formation of the self-etching system (Clearfil Liner Bond II Σ) was 41.7±6.3% and that of the self-priming system (Single Bond) was 38.2±3.9%; there was no significant difference.

Conclusions. Approximate three-dimensional images of the in vitro contraction gap could be drawn and the mean proportions of the interface with gap formation could be more precisely calculated than by previous methods.

Introduction

Contraction gap formation at the interface of restoratives between filled materials and the cavity wall is one of the main causes of pulpal inflammation from microleakage or recurrent caries after filling dental restorative materials.[1–4] For prevention of such symptoms, many dentin bonding systems have been developed for adhesive restorations to improve bonding ability, and incremental filling and curing techniques; for example, the two step curing[5–7] and pulse curing[8] techniques have been investigated and developed for composite resin restoratives. In in vitro studies, the bonding ability of such systems and the effectiveness of

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the filling and curing techniques have been evaluated by various testing methods that detect gap formation.[5-16]

In general, the various methods to detect gap formation include the use of dyes,[9-13] chemical tracers[14,15] radioactive tracers[16,17] or scanning electron microscope (SEM) using a replica method.[18,19] With these methods, except for SEM observation, after the extracted tooth including the restorative was immersed into a tracer solution, the tooth was sectioned and the extent of penetration of the tracer in the sections observed. In SEM observation, after the tooth was sectioned, a replica was taken using an epoxy resin. However, with these methods, penetration of the tracer or the observation of epoxy replica was evaluated in one or just a few two-dimensional sections of the restored tooth.[20] Therefore, three-dimensional gap formation was not evaluated by these methods. To overcome this drawback, Gale et al. reported a three-dimensional method that evaluated dye penetration at the adhesive interface of resin restoratives.[21] In their method, images of the reduced sectional surface of the resin restoratives were taken with continuous reductions, and three-dimensional images were made using computer software from each obtained image. However, with methods where a tracer penetrates, including the three-dimensional dye penetrating method, a contraction gap not connecting with the external margins where residual bacteria grow, was not always detected. Tracer sometimes penetrated into the some tissues and restorative materials without an interfacial gap; therefore, these methods using tracer penetration may not be always accurately show the extension of interfacial gap formation.

On the other hand, quantitative methods for detecting gap formation, such as an air pressure[22,23] and electrical[24-26] methods have been reported. In the air pressure method, air was delivered under pressure to the floor of the cavity of the restorative and the release of air bubbles from the margin of the submerged restorative were observed under a microscope.[23] This method is quantitative for evaluating the amount of air bubbles, but cannot show the location of the gap formation at an internal interface between a cavity wall and the filling materials.[20] The electrical method for evaluating the amount of the contraction gap measures electrical conductivity, but it too cannot show the location of the gap formation.[24-26] In addition, Youngson reported that the extension of a dye along the cavity wall was evaluated three-dimensionally by overlapping many images of sample sections, and that the amount of the extension of the dye was presumed.[27] However, this tracer penetration method may not be always accurately show the extension of a gap; as noted above.

Therefore, it is necessary to accurately evaluate, with and without connecting the external margins, both three-dimensional extensions and the amount of interfacial gap formation. This study aimed to design a new quantitative three-dimensional method for evaluating the location and amount of gap formation at the interface of restoratives, including the gap not connecting with the external margins, using a high-power stereoscopic microscope and computer analysis.

Materials and methods

Preparation of specimens

Two dentin bonding systems, a self-etching system (Clearfil Liner Bond II Σ, Kuraray Co., Ltd., Osaka,

Table 1 The dentin bonding systems used in this study.

Code	Product	Bonding system		Batch No.	Procedure	Manufacturer
LB	Clearfil liner bond II Σ (self-etching system)	Self-etching primer	Primer A Primer B	00114A 00111B	Mix, 30 s apply 5 s air-blow	Kuraray Co., Ltd., Osaka, Japan
		Bonding agent		00186B	Apply, air-blow 20 s cure	
	Clearfil AP-X A3			00924A	40 s cure	
SB	Single bond (self-priming system)	Etchant		2FH	15 s etch, 10 s rinse, blot dry (cotton)	3M ESPE, St. Paul, MT, USA
		Adhesive		2GL	Apply, 5 s air-blow, (two times), 10 s cure	
	Z250 A3			3LGJ	20 s cure	