Bull. Tokyo Med. Dent. Univ., 28: 45–51, 1981

TAGS PENETRATING DENTIN OF A NEW ADHESIVE RESIN

BY

Masaaki IWAKU*1, Isamu NAKAMICHI*1, Katsufumi NAKAMURA*1,
Kyoichi HORIE*1, Syuji SUIZU*2 and Takao FUSAYAMA*1

ABSTRACT

The change of the dentinal tubules by acid-etching and the morphology and the adhering state of new adhesive composite resin tags penetrating the tubules were observed by SEM, comparing with the representative conventional composite resin.

When the fractured surfaces of the unetched floor dentin were observed, all tubule entrances were closed by blocking with cutting debris up to 10 to 20 μm depth. Etching opened them by dissolving the debris and further widened the tubule entrances up to 10 to 20 μm depth by dissolving the peritubular dentin near the apertures.

Resin tags penetrated 10 to 20 μm in vital teeth, 60 to 100 μm in freshly extracted teeth and several hundred μm in old extracted teeth.

The tags of the new resin penetrating the tubules copied exactly the shape of the tubule walls, producing hollow depressions at the ends, indicating that the resin polymerized, adhering tightly to the walls, while those of the conventional resin produced highly tapered side walls with pointed ends, indicating that the resin shrank separating from the tubule walls on polymerization.

The new resin did not produce any gap at the resin-dentin interface unlike the conventional resin.

INTRODUCTION

A restorative resin adhering strongly to the tooth substance was finally realized by the development of Clearfil Bond System-F (Clearfil in short—Kuraray Corporation, Ltd., 1–12–39 Umeda, Osaka, Japan) in 1976. This was the first resin that showed some significant adhesion to both enamel and dentin even without etching, and etching increased the adhesion remarkably (Fusayama *et al* [1]). Considering the unique feature that this adhesion to dentin increased remarkably by etching and confirming that etching dentin did not harm the pulp with this material (Inokoshi [2]), Fusayama [3] established the clinical procedure of its use by the total etching technique, in which all of cavity walls including dentin are etched.

In this study, the change of the dentinal tubules by etching and the morphology of the resin tags penetrating the dentinal tubules were investigated, comparing with the representative conventional composite resin in order to clarify the reason for the strong adhesion of the new resin.

MATERIALS AND METHODS

Observation of the change of the dentinal tubules by acid-etching. In order to observe the change of the dentinal tubules by acid-etching *in vivo*, four bicuspids to be extracted for orthodontic reasons were used.

*1 岩久正明・中道　勇・中村勝文・堀江恭一・総山孝雄: Department of Operative Dentistry (Chief: Prof. T. FUSAYAMA), Faculty of Dentistry, Tokyo Medical and Dental University (Tokyo Ika Shika Daigaku).

*2 水津修司: Department of Conservative Dentistry (Endodontics and Operative Dentistry), (Chief: Prof. H. MATSUMOTO), School of Dentistry, Nagasaki University (Nagasaki Daigaku).

Received for publication, February 20, 1981.

The buccal cusp of each was reduced to produce a flat dentin surface on which a pair of cylindrical cavities of approximately 0.5 mm depth were prepared mesiodistally by using a No. 56 tungsten carbide bur mounted on an air turbine with spray coolant. In one of them all of cavity walls was etched with a jelly-like paste etchant containing 40% H_3PO_4 (Clearfil etching agent) for 60 seconds, washed with water and dried with air. Both cavities were sealed with a temporary stopping by placing cotton pellets on the cavity floor. After extraction, longitudinal grooves were cut on the mesial and distal surfaces and the tooth was scissored with forceps to produce a vertical fracture surface through the center of both cavities. The floor and fracture surfaces were gold-coated and observed by scanning electron microscopy.

Observation of resin tags penetrating dentin. In order to observe the resin tag penetration *in vino*, a pair of cylindrical dentin cavities described above were prepared in each of the four bicuspids to be extracted for orthodontic reasons. All of the cavity walls including dentin were etched with the etchant for 60 seconds, washed with water and dried with air. One of the pair was filled with the new chemical adhesive composite resin, Clearfil, and the other with the representative conventional so-called adhesive composite resin, Adaptic Total System, (Adaptic in short-Johnson & Johnson Dental Products Company, East Windsor, N.J., U.S.A.) by the technique written by the manufacturer using their bonding agents. The teeth were extracted after the resin set in.

In order to compare the tags penetrating vital dentin in the mouth with those penetrating the dentin immediately after extraction, the upper incisor to be extracted for unusual tipping was used. Four cylindrical cavities as described above were prepared on the facial surface and totally etched by the technique described above. The incisal two of the four cavities were filled with the new resin and the conventional resin. Immediately after extracting the tooth, the gingival two cavities were filled with the two resins.

In order to observe the tags penetrating the dentin of old extracted teeth, a pair of cylindrical cavities were prepared on the occlusal surface of each of the five bicuspids stored in water for more than a year and filled with the two kinds of resins.

The inorganic substance of the filled teeth was removed by dissolving in 10% HCl solution and then the organic substance in 10% NaOH solution. The remaining resin specimens were cleansed by 10% NaOCl and 3% H_2O_2 solutions. After gold-coating, the resin surfaces which set against the dentin were observed by scanning electron microscopy.

Observation of resin-dentin interfaces. In order to observe the adhering state of the resins to the dentin, two pairs of cylindrical cavities were prepared on the occlusal surfaces of two freshly extracted young upper third molars. They were filled with the two resins after total etching. Profile sections of the resin-dentin interfaces were prepared by cutting the teeth vertically through the center of the cavity floors and observed by scanning electron microscopy.

RESULTS

Change of dentinal tubules by acid-etching. Of the unetched dentin surfaces of the cavity floor, all apertures of the dentinal tubules were almost closed, barely showing their location (Fig. 1, *top-left*). Of the etched surfaces, most apertures were open, widening to 3 to 5 μm in diameter (Fig. 1, *top-right*).

When the fracture surfaces parallel to the tubules were observed, the unetched floor dentin showed the tubule entrances

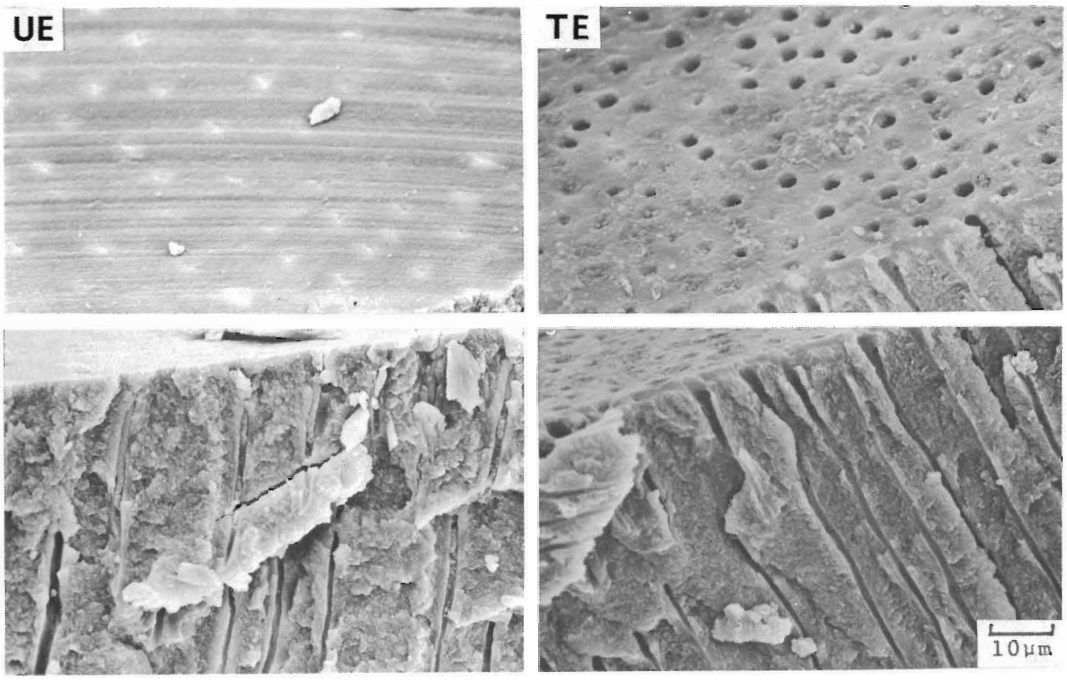


Fig. 1. The cavity floors (*top*) and their fractured surfaces (*bottom*) which were unetched (*left*) and etched (*right*).

blocked with cutting debris up to 10 to 20 μm depth (Fig. 1, *bottom-left*). The etched floor dentin showed the tubule entrances completely open without the cutting debris blocking. The tubule entrances were further widened in funnel shape up to 10 to 20 μm depth, increasing the diameter of the apertures approximately three times (Fig. 1, *bottom-right*).

Depth of tag penetration. The depth of tag penetration into the etched dentin of the vital teeth in the mouth was usually 10 to 20 μm, rarely exceeding 30 μm (Fig. 2, *left*). That of the tooth immediately after extraction was as large as 60 to 100 μm (Fig. 2, *center*). That of the old extracted teeth was still larger reaching several hundred μm (Fig. 2, *right*). Such a similar variation was observed with both the conventional and the new resins. Although some tubules from which the cutting debris blocking failed to be removed by etching were not penetrated, the depth of penetration not vary between the two resins.

Morphology of resin tags. When the tags penetrating the etched dentinal tubules of the vital dentin were observed under high power magnification, those of the conventional resin showed highly irregular knotty surfaces, the side walls tapering more than the taper of the etched entrances of the tubules and mostly with pointed ends (Fig. 3, *left*). In contrast, those of the new resin showed smooth surfaces, copying exactly the tubule shape, the column side walls without tapering more than the taper of the etched tubule entrances and with hollow depressions at their ends (Fig. 3, *right*).

The long tags penetrating the extracted teeth, however, showed fairly smooth-surfaced long columns similarly to both materials except that their ends often showed the difference described above (Fig. 2).

Profile of resin-dentin interfaces. When

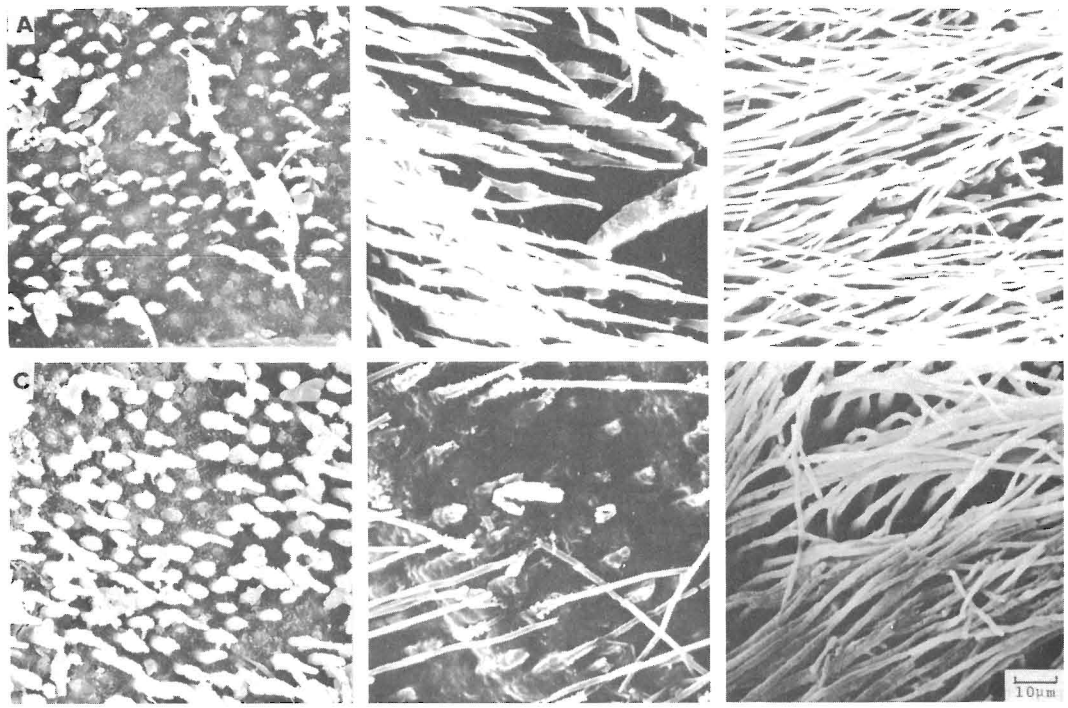


Fig. 2. Length of resin tags of the conventional resin (*top*) and the new resin (*bottom*) penetrating the dentinal tubules of vital teeth (*left*), teeth immediately after extraction (*center*) and old extracted teeth (*right*). Some tubules failed to be penetrated simply because the cutting debris blocking the tubule apertures was not completely removed.

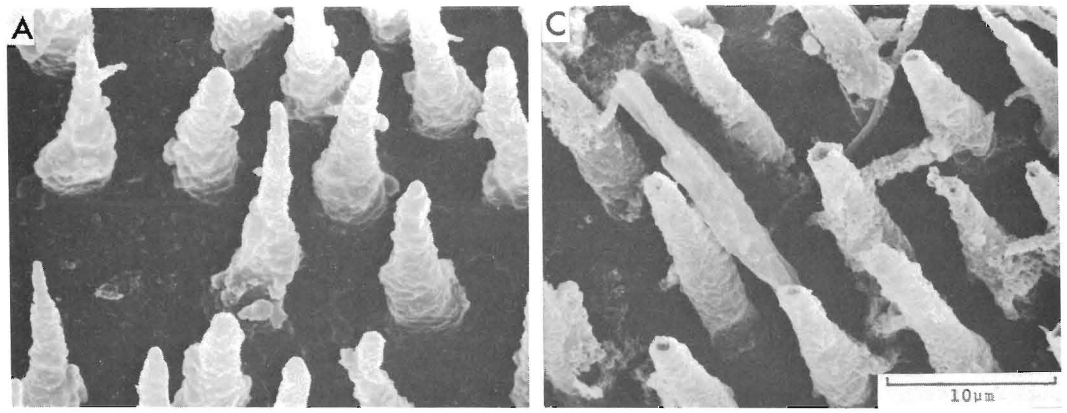


Fig. 3. The tags of the conventional resin (*left*) and the new resin (*right*) penetrating the dentinal tubules of vital dentin observed under high power magnification.

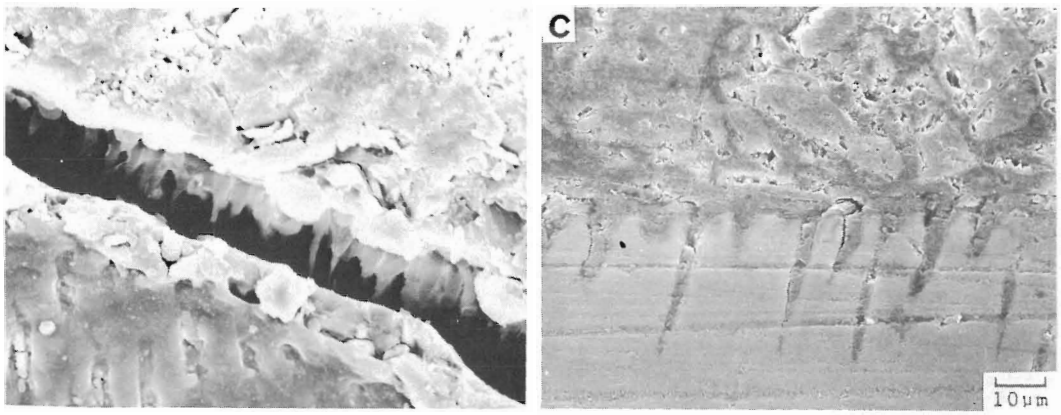


Fig. 4. Profile sections of resin-dentin interface of the conventional resin (*left*), and the new resin (*right*) filled in the freshly extracted teeth after total etching.

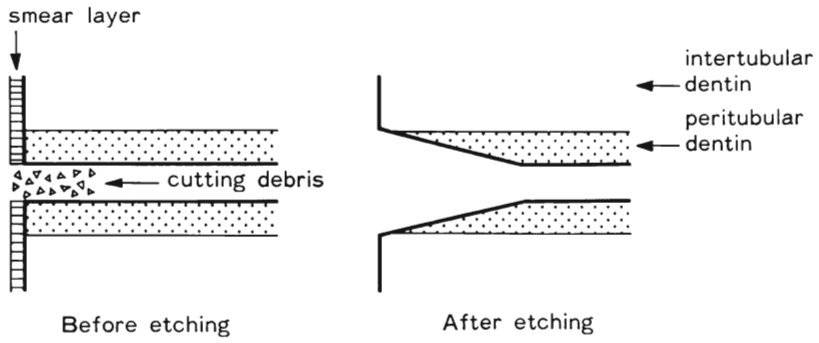
the profile sections of the interfaces were observed by scanning electron microscopy, the conventional resin was found approximately 10 μm separated from the dentin floor, pulling the tags out of the tubules, whereas the new resin showed a tight adhesion to the dentin floor as well as to the tubule walls, producing no gap along the cavity floor and some voids in the tags (Fig. 4).

Discussion

Change of dentinal tubules by acid-etching. In accordance with the report of Brännström [4], etching opened the blocked tubules by dissolving the cutting debris and widened the entrances in funnel shape by dissolving the peritubular dentin near the apertures (Fig. 5). Some tubules, however, remained closed because the blocking debris was too dense to be completely dissolved.

Depth of tag penetration. Both resins used with their bonding agents could penetrate the etched dentinal tubules. The depth of penetration did not vary between the two resins but varied considerally depending on the freshness of the teeth. Thomas [5] reported that the odontoblast processes in the tubules of the impacted third molars were usually limited to the inner third of the dentin thickness, leaving lumen lined with a limiting membrane in the middle and outer third. Gunji, Wakita and Kobayashi [6], however, found by means of the HC1 collagenase method to remove the dentin matrix that the odontoblastic processes of the young permanent teeth definitely reached close to the enamel dentin junction. It is thus clear that the regular dentinal tubules have a lumen almost reaching the junction and are filled with the organic structure. Etching the dentin floor of the vital teeth seemed to be able to remove the structure only to a limited depth of 10 to 20 μm. When a tooth is extracted, the resin penetrated further, probably because the inner pressure supporting the structure was removed (Moist & Yannof [7], Eiskin [8]). The tag penetration in the old extracted teeth, however, was still deeper. The organic structure in the tubules seemed to be broken or dissolved by deterioration after long storage.

Adhesion of resin tags. Morphology of the short tags penetrating the vital dentin (Fig. 3) and the profile view of the resin-dentin floor interfaces (Fig. 4) revealed a marked difference in the adhering state between the conventional resin and the new resin. The tags of the conventional resin showed mostly higher taper-forming



CHANGE OF DENTINAL TUBULE APERTURES BY ACID ETCHING

Fig. 5. Schematic illustration of the change of the dentinal tubule apertures by acid-etching of the vital dentin wall. Etching opens the tubule apertures by dissolving the smear layer, the cutting debris blocking, and a part of the peritubular dentin of funnel shape.

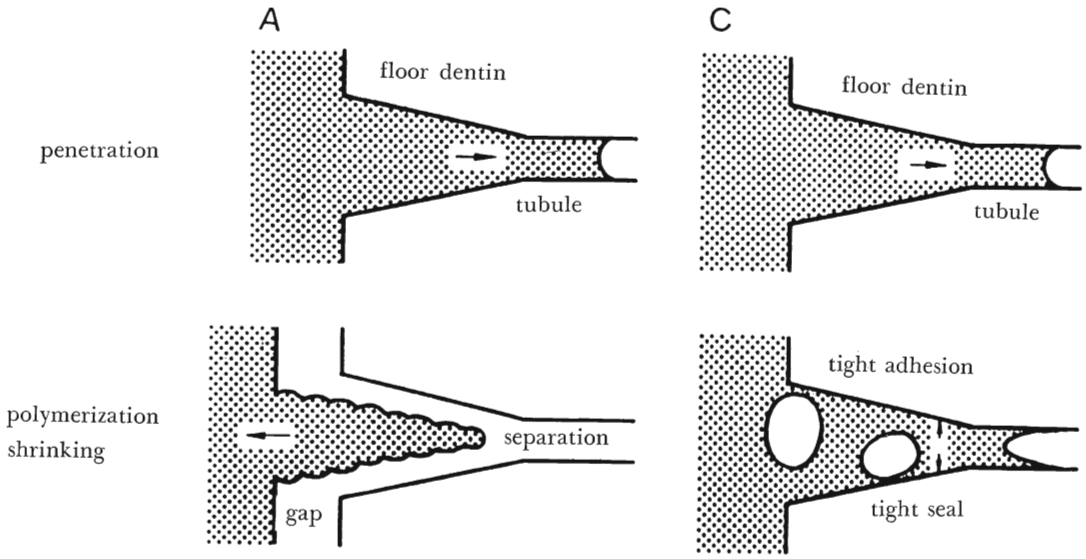


Fig. 6. Schematic comparison of the adhering states of the conventional resin (*left*) and the new resin (*right*) tags penetrating the etched dentinal tubules. On polymerization shrinking, the new one has a tight adhesion to the tubule wall resulting in no gap on the cavity floor whereas the conventional one separates from the wall resulting in a gap in the cavity floor.

pointed ends and irregular knotty surfaces, because they shrank freely, separating from the tubule walls during polymerization. The resin, therefore, separated from the cavity wall, pulling the tags out of the tubules (Fig. 6 *left*). In contrast, most tags of the new resin showed the exact copy of the tubule walls and hollow depressions at their ends. This is considered to be because the new resin penetrating the tubules polymerized, showing a tight adhesion to the tubule walls, and shrank, producing voids in the bulk and hollows at the ends. No gap was thus produced along the cavity wall (Fig. 5 *right*).

Fusayama *et al* [1] Previously showed by the tensile adhesion test that the new resin had a strong adhesion to the etched dentin wall, unlike the conventional composite resins. The morphology of the tags with

a tight adhesion to the tubule walls seems to account for the strong adhesion of the new resin to the dentin. Such a tight seal of the tubule entrances by adhesion is considered also to prevent the irritants from penetrating and accounts for the fact that the pulp irritation of the new resin filling is very slight (Miyauchi *et al* [9]) and that the total etching including the dentin wall rather decreases the pulp irritation instead of increasing it (Inokoshi [2]).

References

[1] Fusayama, T., Nakamura, M., Kurosaki, N. and Iwaku, M.: Non-pressure adhesion of a new adhesive restorative resin. J. Dent. Res., 58: 1364–1370, 1979.

[2] Inokoshi, S.: Pulp response to a new adhesive restorative resin. J. Stomatol. Soc. Jap., 47: 410–426, 1980.

[3] Fusayama, T.: New Concepts in Operative Dentistry, Quintessence Pub. Co., Chicago, 1980.

[4] Brännström, M. and Johnson, G.: Effects of various conditioners and cleaning agents on prepared dentin surface: A scanning electron microscopic investigation. J. Prosthet. Dent., 31: 422–430, 1974.

[5] Thomas, H.: The extent of the odontoblast process in human dentin. J. Dent. Res., 58: 2207–2218, 1979.

[6] Gunji, T., Wakita, M. and Kobayashi, S.: Distribution and contraction of odontoblast processes in human dentin by SEM. Read before the Annual Meeting of IADR, Japanese Division, Tokyo. 1980.

[7] Moist, R. and Yannof, H. M.: Measurement of pulpal blood pressure. J. Dent. Res., 44: 570–573, 1965.

[8] Eiskin, M.: The Biology of the Human Dental Pulp. 1st ed., Mosby, St Louis, 1973, pp. 16–24.

[9] Miyauchi, H., Itoh, K., Shimizu, C., Kurosaki, N., Hachiya, Y. and Iwaku, M.: Pulp response to a new adhesive restorative resin "Clearfil Bond System-F" (in Japanese, English abstract). Jap. J. of Conserv. Dent., 21: 384–387, 1978.