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NEW RESTORATION AND DIRECT PULP CAPPING SYSTEMS USING ADHESIVE COMPOSITE RESIN

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ABSTRACT

There have been many arguments on the irritating mechanisms of the composite resin on the dental pulp. While the direct irritative effect of the resin has been prefered, some authors considered that the marginal microleakage and the resulting bacterial infection play a more important role in inducing the complicating pulp irritation. We developed a new filling technique, called the direct inlay restoration method, which could prevent the marginal leakage associated with the polymerization shrinkage of the adhesive composite resin.

In this study, we tried to apply our method clinically. None of the 440 cases which were filled with the adhesive composite resin and 60 cases out of 64 cases in which the pulps were directly capped with the adhesive composite resin developed any signs and symptoms of pulp irritation. The other 4 cases developed signs of pulp irritation. Two of those 4 cases were pulpectomized due to spontaneous pain and the other 2 cases turned out to be well after re-restoration. With the informed consent of the patients, the direct pulp capping using the adhesive composite resin was experimentally performed on 6 caries-free 3rd molars and the histopathological examination of these capped molars revealed that neither significant degenerative nor inflammatory changes were brought about in the dental pulp.

These clinical and histopathological observations suggest that the dental pulp irritation after resin filling is not induced by the composite resin itself.

Key words: Adhesive composite resin, Filling, Direct pulp capping, Dental pulp irritation

INTRODUCTION

Composite resins have begun to attract attention as a crown restorative material because they have excellent esthetic properties and are easy to handle and adhere well to the dental hard tissue when used with a bonding agent. Recently its physical properties and adhesive strength have been improved and the composite resin has come to be used widely in today's dentistry (Horn [1]). However, several troubles such as dental pulp irritation and necrosis often occur after the composite resin filling, even if the operations are carefully performed according to the usual procedure by which the deep cavities which will cause severe cold pain should be lined and the shallow cavities which will cause little cold pain need no linings.

Many dentists suspect the composite resin itself to be the cause of pulp irritation because the pulp irritating effect of the composite resin has long been pointed out by many authorities since the beginning of

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its clinical application (Langeland et al. [2]; Stanley, Swerdlow and Buonocore [3]; Rao [4]; Fujisawa, Sunada and Masuhara [5]; Stanley, Bowen and Folio [6]; Aoki et al. [7]; Kasai [8]; Kubo [9]). But recently there are several arguments that the pulp irritation after composite resin filling must be related with the bacteria which will penetrate into the dental pulp through the marginal leakage from the oral microbial flora or which will remain in the dentin cavity wall after cavity preparation (Torstenson et al. [10]; Inokoshi [11]; Inokoshi et al. [12]; Kanehira [13]; Fujitani [14]). These bacteria could grow in a gap between the resin and the cavity wall into which the tissue fluid might exude through the dentinal tubules opening on the dentin cavity floor and the oral saliva might sink through the marginal leakage.

It was also reported that the composite resin itself had no chemical irritating effect on the pulp (Brännström and Nyborg [15–17]; Brännström and Nordenvall [18]; Brännström [19]). Fusayama [20] reported that the pulp irritation might be caused by the pumping action onto the open dentinal tubules but not by the chemical irritating effect of the composite resin. Polymerization shrinkage which is an inevitable phenomenon in the curing of the composite resin might bring about the detachment of the resin from the cavity, and the dentinal tubules would open in the gap between the cavity floor and the resin. The volume of this gap might be changed by temperature and occlusal pressure. This change of the volume will produce a pumping action which might force the tissue fluid and others into the dentinal tubules and might irritate the pulp. The marginal leakage could play a more crucial role of pulp irritation (Inokoshi [11]). The marginal leakage could promote the penetration of the bacteria and other irritants from the oral cavity into the dentinal tubules, which might also irritate the pulp.

In order to prevent the marginal leakage and detachment of the resin filling from the cavity, one of us devised a new restoration method, called a direct inlay restoration method (Kashiwada [21]; Kashiwada et al. [22]; Kashiwada and Kayano [23]). In this method, the composite resin inserted in the cavity was light-cured and this light-cured resin was detached from the cavity. This resin inlay was set in the cavity with a bonding agent. According to this procedure, polymerization shrinkage of the composite resin curing could be minimized. It was already demonstrated by the thermal cycle test that no marginal leakage occurred in the composite resin restroration which was filled in the extracted teeth by the direct inlay restoration method (Kashiwada [21]; Kashiwada et al. [22]; Kashiwada and Kayano [23]). In this report, some possibilities of the clinical application of this new method to the conservative restoration of the vital human teeth and also to the direct pulp capping were evaluated clinically and histopathologically.

Materials and Methods

I. Clinical application of composite resin filling

Four hundred and forty cases of Class V cavity were filled with the adhesive composite resin by 6 dentists from October 1987 to March 1989 according to the procedure of the direct inlay restoration method as follows: (1) Cavity preparation: A caries lesion is removed and a cavity without retention form is prepared. A wedge-shaped defect can be used as a cavity without any preparation. (2) Direct inlay technique: Adhesive composite resin (Photo Clearfil Bright, KURARAY Co., Ltd.) which is one step darker than the just matched shade resin is inserted into the cavity. After light-curing, the resin is removed from the cavity with an excavator.

The cavity surface of the resin inlay is light-cured to polymerize completely. The overfilled resin projecting from the inlay edge is trimmed. The resin inlay is washed with water and is finished with drying after dripping of absolute alcohol. (3) Setting of the resin inlay: The cavity is totally etched with 40% phosphoric acid solution for 30 seconds and is washed well with water. Then absolute alcohol is dripped in the cavity and the cavity is dried well with air spray. A bonding agent (Clearfil Photo Bond, KURARAY Co., Ltd., mixed with Clearfil Porcelain Bond Activator, KURARAY Co., Ltd.) is applied to the cavity wall and is blown with air spray to make a thin film of the bonding agent. The film is light-cured for 20 seconds. The bonding agent is also applied to the resin inlay and is blown with air spray. Thė resin inlay is set in the cavity with a low-viscosity composite resin (Clapearl DC, KURARAY Co., Ltd.) and the excess resin is wiped away with a brush. The resin inlay set in the cavity is light-cured for more than 40 seconds, being held against the cavity with the brush handle. Finally the resin inlay is polished in the usual manner.

The patients consisted of 149 males aged from 15 years to 67 years and 291 females aged from 15 years to 73 years. The treated teeth were composed of 60 incisors (24 upper/36 lower), 118 canines (67 upper/51 lower), 242 premolars (140 upper/102 lower) and 20 molars (13 upper/7 lower). Those patients were recalled 1 and 3 weeks after the treatment and the prognosis was checked for more than 2 years until February 1991 by questioning and applying air blow or cold water to the treated teeth.

II. *Direct pulp capping using adhesive composite resin*

A. Clinical examination

With the consent of the patients, 64 cases were directly capped with a composite resin by 6 dentists from September 1988 to August 1989 according to the procedure as follows: (1) Sterilization of the exposed pulp and dentin cavity wall: After the caries lesion which is stained with a caries detector is completely removed, 10% sodium hypochlorite solution is applied on both the exposed pulp and the dentin cavity wall for about 4 minutes in order to stop the bleeding and sterilize the exposed pulp and the cavity. (2) Direct capping with the adhesive composite resin (Fig. 1): The cavity is washed with water and dried with soft air spray and the bonding agent (Clearfil Photo Bond, KURARAY Co., Ltd.) is dripped on the exposed pulp surface and the surrouunding dentin and is blown with soft air spray. After the bonding agent is light-cured for 40 seconds, a sealant agent (Teeth Mate A, KURARAY Co., Ltd.) is dripped on the light-cured bonding agent and is blown with soft air spray and light-cured for 40 seconds. The sealant is layered more than 0.5 mm thick enough to withstand the mechanical pressure.

Forty-three cases of these direct-capped teeth were restored with porcelain inlays and onlays and the other cases were restored with metalic inlays and onlays. These porcelain inlays and onlays were cemented with Clapearl (KURARAY Co., Ltd.) in combination with Clearfil New Bond (KURARAY Co., Ltd.), and Clearfil Porcelain Bond Activator (KURARAY Co., Ltd.), and these metalic inlays and onlays were cemented with Panavia EX (KURARAY Co., Ltd.) in combination with Clearfil New Bond (KURARAY Co., Ltd.).

The patients were composed of 15 males aged from 15 years to 53 years and 49 females aged from 15 years to 63 years. The treated teeth consisted of 2 upper incisors, 5 canines (2 upper/3 lower), 42

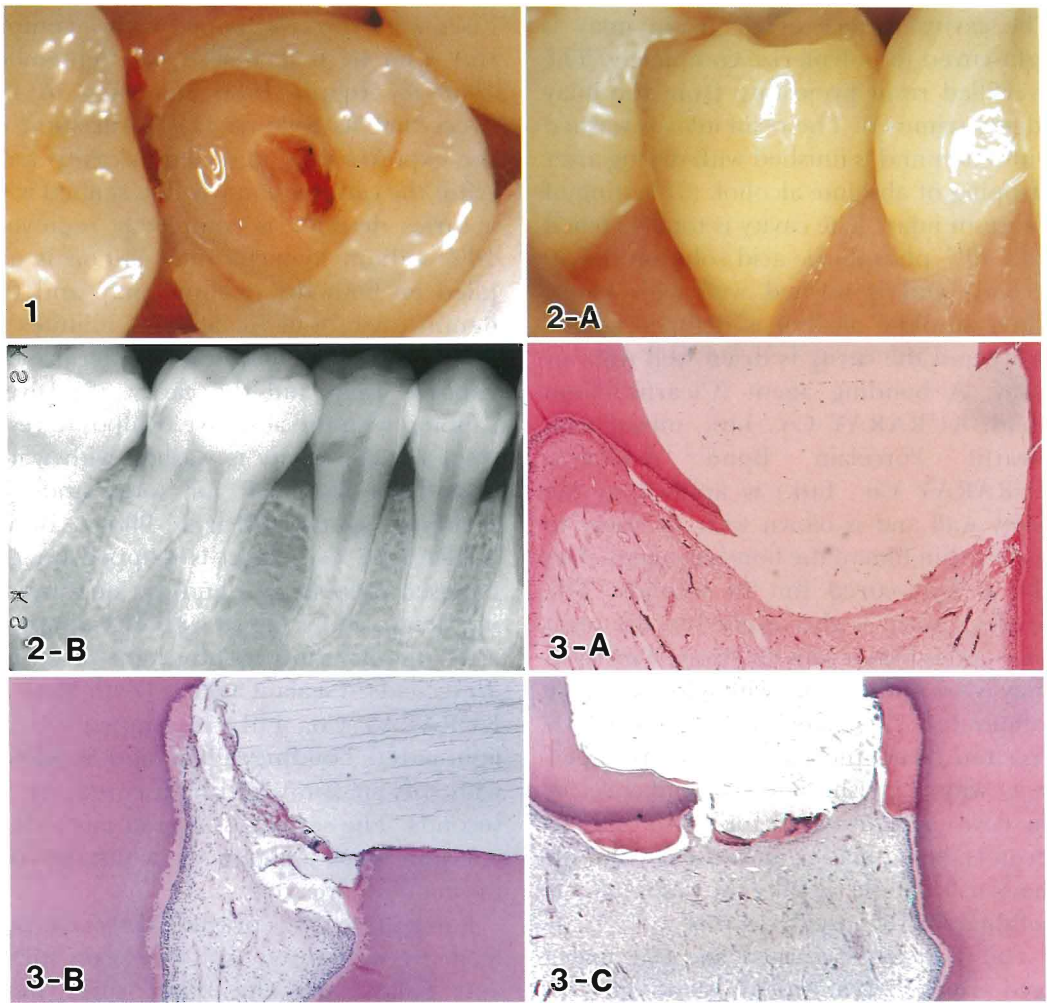

Fig. 1. **Direct Pulp Capping Using Adhesive Composite Resin**
The pulp was exposed after complete removal of the caries lesion and the exposed pulp was sterilized with 10% sodium hypochlorite. The exposed pulp surface and the dentin cavity floor were covered by a sealant agent in combination with the bonding agent. Mandibular 2nd premolar of a 32-year-old male.

Fig. 2. **Two Years and 4 Months After Direct Pulp Capping With Adhesive Composite Resin and Porcelain Onlay Restoration**
Neither symptom nor sign of pulp irritation or pulp necrosis (A) and no periapical lesion on X-ray image (B). Same case as shown in Fig. 1.

Fig. 3. **Histopathology of Direct Pulp-Capped Teeth With Adhesive Composite Resin**
Because of the decalcified histologic sections, the enamel and the resin have disappeared.
(A) One month after the treatment: No inflammatory cell infiltration but mild hyperemia of the pulp. Odontoblastic layer adjacent to the pulp exposure did not show any degenerative change and proliferation. Maxillary 3rd molar of a 25-year-old female.
(B) Six months after the treatment: A thin-layered calcified tissue was formed on both the exposed pulp surface and the dentin cavity floor. There was no inflammatory cell infiltration. Mandibular left 3rd molar of 25-year-old male.
(C) Twelve months after the treatment: A thin

premolars (22 upper/20 lower) and 15 molars (8 upper/7 lower). The patients were recalled and the prognosis was checked by questioning and applying air blow or cold water to the treated teeth for more than 1 year and 6 months until February 1991.

B. Histopathological examination

With the consent of the patients, 6 caries-free 3rd molars (4 upper/2 lower) of 5 persons (3 males and 2 females) aged from 22 years to 38 years were used for the experiments. These teeth were indicated for extraction because of chronic pericoronitis. Under local anesthesia, a Class I boxed shaped cavity was prepared with a diamond point with water spray. The center of the cavity floor was drilled to expose the pulp and the exposed pulp was directly capped with the composite resin in the same manner as by the above procedure. These direct-capped teeth were restored with the adhesive composite resin by the direct inlay restoration method.

The patients were recalled regularly and the treated teeth were checked clinically and 2 teeth were extracted for histopathological examination each time at 1, 6 and 12 months after treatment, respectively. For better fixation of the dental pulp, the roots of each extracted tooth were cut off with a diamond disk with water spray. Each specimen was fixed in a neutral 10% buffered formalin solution for 2 weeks and decalcified in the Plank-Rychlo solution for 7 days. After decalcification, the specimens were embeded in paraffin and were serially cut at 6 μm thickness. These histological sections were stained with haematoxylin-eosin and examined histopathologically.

Results

I. *Composite resin filling*

None of the patients whose teeth were filled with composite resin according to the direct inlay restoration method did complain of any discomfort. None of the 440 experimental cases did develop any pulp pain and necrosis during the long followup period. Only one patient complained of discomfort immediately after the treatment, however he had no problem at the next visit 2 weeks later.

II. *Direct pulp capping using adhesive composite resin*

A. Clinical examination

One year after the treatment, 60 cases were vital by pulp electrodiagnosis and the patients complained of no discomfort (Fig. 2). The other 4 cases developed signs of pulp irritation. Two of the 4 cases developed occlusal pain immediately after treatment and spontaneous pain 2 weeks later and were pulpectomized. These were cases of large and deep dentin caries of the lower 1st molar of 30- and 33-year-old females, respectively. At pulp extirpation, marginal gaps were found between the restored and the cavity wall. In the other 2 cases, a large and deep dentin cavity was restorated by an onlay. An occlusal pain was developed immediately after treatment. The teeth had been discomforting the patients for 1 year, however the teeth had been vital and the pain disappeared after the rerestoration of the teeth.

B. Histopathological examination

The pulp surface in direct contact with the bonding agent showed no regressive changes except mild hyperemia 1 month after treatment (Fig. 3-A). The odontoblastic layer did not show any changes such

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dentin bridge was formed on the exposed pulp surface and a thick secondary dentin was formed at the pulp side of the dentin cavity floor. The underlying pulp was vital and free of inflammatory elements. Mandibular right 3rd molar of a 35-year-old male.

as degeneration and proliferation. A thin-layered calcified tissue covered the exposed pulp surface and extended on the dentin cavity floor 6 months after treatment (Fig. 3-B). The odontoblastic layers adjacent to the pulp exposure did not show any pathological changes. Twelve months after treatment, a thin layer of the dentin bridge developed on the exposed pulp surface and a thick secondary dentin was formed on the pulp side of the dentin cavity floor (Fig. 3-C). Neither inflammatory nor necrotic changes had been seen in the pulp during the long experimental period.

Discussion

In order to prevent the dental pulp irritation after composite resin filling, it is necessary to keep the resin from detaching from the cavity floor and not to cause a marginal leakage. For prevention of marginal leakage, four possibilities were pointed out as follows: (1) To make a composite resin that shrinks in a small degree after polymerization. (2) To prevent a composite resin from detaching from the cavity floor by making the adhesive strength of the liner stronger than the shrinkage strength of the resin polymerization, or to make a new liner which does not adhere to the resin (3) To make the adhesive stength of the resin to the dentin stronger than the strength caused by the polymerization shrinkage of the resin. (4) To adopt a new restoration method which minimizes the degree of the polymerization shrinkage of the resin.

There is no composite resin which shrinks in a small degree after polymerization yet. On the 2nd possibility, several methods including the sandwich technique have been tried but are not satisfactory. A bonding agent which has enough bonding strength might be produced in the future, but now there is no such bonding agent available. In addition, the degree of the adhesive strength of the bonding agent to the dentin varies from one tooth to another and from one area to another of the tooth. It is thus difficult to obtain enough adhesive strength by the conventional restoration methods.

Clinical examination of our new technique, called the direct inlay restoration method, clearly showed that none of the patients who had their teeth treated with our method had complained of any discomfort or pulp irritation, and all of the 440 teeth had been vital clinically during the long experimental period. No marginal leakage of the resin filling which was obtained by this method will not develop any pulp irritation. The degree of the polymerizing shrinkage of the resin depends on the volume of the resin. The previous method of composite resin restoration must bring about polymerizing shrinkage in the cavity which will cause the detaching of the resin from the cavity wall and floor resulting in marginal leakage. According to our new method, the inserted resin is removed from the cavity and is cured well in order to make the polymerizing shrinkage of the resin inlay finish out of the cavity, and the resin inlay is cemented with a low-viscosity composite resin in combination with a bonding agent. In this way, the adhesive composite resin restoration without any marginal leakage will be performed well.

None of those 440 cases were lined and no pulp irritation occurred even in the cases of deep dentin cavity without any liner. This result supports the previous reports that the composite resin itself has no chemical irritative effect on the pulp (Brännström and Nyborg [15–17]; Brännström and Nordenvall [18]; Brännström [19]; Torstenson et al. [10]; Inokoshi [11]; Inokoshi et al. [12]; Kanehira [13]; Fujitani [14]). Our experimental application of the

adhesive composite resin to the direct pulp capping resulted in a good prognosis of the treated teeth without any pulp irritation. Sixty cases of the 64 cases which were experimentally treated with the resin capping did not develop any pulp irritation for more than 1 year after treatment. Only 4 cases developed pulp irritation. The cause of the failure of these cases might be the marginal leakage due to insufficient hemostasis of the exposed pulp and due to the large cavity prepared in the dentin. In these 4 cases, the dentinal tubules were not completely sealed and the resulting pulp irritation may have been caused by the pumping action. Two of the 4 cases had turned out to be well after the re-restoration.

Histopathologically the dental pulps of the teeth directly capped by the composite resin showed neither inflammatory cell infltration nor degenerative changes of the odontoblasts. Later after the treatment a thin dentin bridge was formed on the exposed pulp surface in direct contact with the bonding agent which was applied in combination with the sealant agent. Formative irritants of these dentin bridges might relate not to the composite resin, which was applied on the exposed pulp in combination with the bonding and sealant agents but to the mechanical and thermal stimulations from the oral environment.

The cause of the pulp irritation after the composite resin filling has been controversial since the beginning of its clinical application. Our clinical examination of the direct inlay restoration method and the direct pulp capping method using the adhesive composite resin resulted in success and the treated teeth had been vital without any discomfort or pain due to pulp irritation. Our results revealed that the restoration method which can prevent the polymerization shrinkage of the composite resin and which can produce a tight adhesion between the dentin and the cured resin will not develop pulp irritation even in the case of pulp exposure. Marginal leakage and detachment of the resin from the cavity floor might cause a bacterial infection of the pulp and the pumping action on the pulp through the dentinal tubules.

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