Methods and Factors involved in Bonding Orthodontic Attachments to Enamel

by

Leonard BERNSTEIN*

Introduction

It is quite evident that in the practice of orthodontics, much time could be saved and much tedious labor could be avoided if a method were available to attach a bracket directly to a tooth surface.

The object of this investigation was to determine if this could be accomplished by using Eastman 910 [6], a cyano-acrylate, as a bonding agent. This material is a thin, colorless liquid with a low viscosity and fast setting time, whose vapors in sizable amounts are irritating to mucous membranes.

Initially, it was thought that an epoxy resin would be suitable for this purpose, but investigation showed that the epoxy resins do not have a setting time which would enable them to be of any practical value.

SADLER [10], using commercial adhesives, attempted to bond edgewise brackets to extracted human teeth. He determined that for the most part, the adhesives surveyed showed a lack of adhesion to the metal brackets. He stated that in their present state, none of the adhesives tested were capable of bonding metal attachments directly to the teeth with a stability required for clinical orthodontics.

In an attempt to find a method of bonding acrylic to tooth material, BUONOCORE [2] tested over onehundred commercial resin compositions. He determined that from all aspects, Eastman 910 adhesive rated best for this purpose.

Earlier work with resin cements by SCHOUBOE, et al. [11], showed that the resin cements expand on absorption of water, and they suggest that this may be responsible for the resin cements not adhering to tooth structures under mouth conditions. A rough screening test for adhesion was employed to find out if any of the resin cements used with a direct filling resin were actually adhesive to enamel and dentin under conditions of use. All of the resins showed an initial adhesion to the tooth tissues and, if the tooth and resin were kept dry, the adhesion was so strong that usually the tooth would be broken if an attempt were made to remove the resin. After soaking the tooth with the resin on it in water, however, this adhesion was lost. There were no exceptions and zinc phosphate cement adhered as long as the resin cements. After twenty-four hours of soaking in water, most of the cements could be dislodged easily and after one week, all of them could.

Many acrylic and zinc phosphate cements were used by ROSE, et al. [9], to determine whether they could be used as bonding agents to enamel and/or dentin. Some materials which gave zero readings after five minutes immersion in water required as

* D. M. D., the present paper was delivered before the Annual Meeting of Japan Research Society for Dental Materials and Appliances held in Tokyo, 1965.

much as seventy-five pounds of tensile pressure to separate when tested dry. In general, they found that very few of the products available to the profession today consistently maintained adhesion after immersion in water for five minutes. After sixteen hours in water, readings on the tester were invariably zero with materials tested. They concluded that, in general, plastics with a high water sorption are not useful as dental adhesives because of their tendency to swell and change dimensions as the water sorption occurs. They determined that water results in a degradation of the adhesive bond a short time after immersion, and concluded that the behavior of adhesives when tested on dry teeth has no direct bearing on the potential adhesion of the same material in the presence of moisture. They found that no product presently available for testing consistently maintained adhesion after prolonged water immersion.

Preliminary Investigation

Initially, six extracted human teeth were set up in plaster. The 910 was applied to various edgewise brackets and these were placed against the tooth surface. After setting, the plaster embedded teeth were set to soak in water to partially simulate an oral environment. The brackets did adhere initially, but after soaking in water for a relatively short period of time, the bonds were easily broken. It was concluded that one of the problems was getting enough surface to surface contact between the bracket and the tooth. It became evident that a way to accomplish this would be to imbed brackets in a resin matrix. These could be more readily adapted to conform to a tooth surface.

Method

Three extracted human teeth were set up in plaster and an area on the buccal surface was squared off with wax. A thin layer of a commercial self-curing acrylic was placed in this area by the "salt and pepper" method. Then an .031 wire hook was bent and placed on it so that the hook stood out free. More acrylic was placed over this and it was allowed to cure, then trimmed and polished. The under surface of these attachments were coated with 910, placed back on the tooth surface, and allowed to set; setting time taking approximately one minute. After soaking in water for three days, the sample was sent to a laboratory to determine how strong a direct and shearing force would be necessary to dislodge the attachments. The results were that the .031 wire hook was torn out of the acrylic when pressure was applied by a tension meter.

It was necessary to prepare attachments of this type with edgewise brackets embedded instead of a hook. A metal bracket was attached to a small square of steel band material and the above process carried out. The next procedure was to place uncured resin on the under surface of this attachment and then to place this against a tooth surface or a model die of a tooth. The new acrylic would then cure with the surface of the die of the particular tooth involved or the tooth itself as its under surface. The object being that this stage would be accomplished by the orthodontist directly on the tooth or in a laboratory on models.

Specifically, some pieces of .004 stainless steel band material, no more than a quarter inch in length, were cut. To each one was spot welded a smaller piece of this band material. To these were spot welded various types of brackets and tubes. The

grooves and slots of the brackets were covered over with wax so that the acrylic would not flow into them. A glass slab was then sectioned off with base plate wax strips which divided it into squares of appropriate sizes to hold the metallic pieces. Acrylic was placed in these squares by the "salt and pepper" method, then the metal squares were placed on the squares of acrylic, and more acrylic was added over this. These were allowed to cure, after which the wax was flushed away with hot water and the squares trimmed and polished. These were called type A.

The next type of attachments to be fabricated would have for their under surface the general configuration of molar, bicuspid and anterior teeth. With this type, it would be possible to preform these attachments and place them directly on the respective teeth with the bonding material without having to utilize the intermediate step of adding more acrylic to gain the conformity of each individual tooth. The technic here utilized the same process for the metal parts as was done previously. The metal parts were then luted with wax to the buccal contour of preformed orthodontic bands and an area squared off on these bands by wax strips. By the "salt and pepper" method, acrylic was then placed in these squares, allowed to cure, the wax allowed to wash away in hot water, then trimmed and polished. The under surface of these attachments now had the configuration of the buccal surface of a tooth. These were called type B.

Six extracted human teeth were set up in an arch form in plaster, an alginate impression of this was taken and a model poured. The three teeth on the right side of the plaster model were painted with a separating medium. Three of the type A brackets were taken, some self curing acrylic applied to the under surface, and this placed against the plaster model teeth and allowed to cure. These were then trimmed and polished. The 910 bonding material was applied to this new under surface and the attachments were placed and allowed to set against the buccal surface of the three plaster embedded teeth on the right side of the model.

On the left side of the model, three type B brackets with their under surface having the configuration of the buccal surface of a tooth were taken, bonding material applied, and these were placed on the buccal surface of the three other extracted teeth on the left side and allowed to set. The whole model was then placed in water to simulate an oral environment. After four days, the model was taken from the water and an .022 by .028 wire with multi-directional torque plus an inter-tooth open coil was placed in the rectangular slot of the attachments. During manipulation, one of the type B attachments on the left side came off. Then .010 ligature wires were used to secure the rectangular wire to the five remaining teeth and it was placed back in the water.

Results

After ten days, the model with the rectangular wire was checked, the type B attachments on the left side, and the type A attachments on the right side were both holding. After two weeks, the model with the rectangular wire was checked and all attachments still held. On the twentieth day, the model was again removed and tested. This time the type B attachments were dislodged. On the thirty-eighth day, the model was again removed and this time the most distal attachment on the right side was dislodged. Four days later, one of the remaining two was dislodged and two days

following, the last one was dislodged. Each time the model was tested, strong digital pressure was exerted against each attachment and against sections of the wire.

Discussion

Due to the fact that all of these attachments were fabricated by hand, the finesse of machine production could not be realized.

The rectangular slot on these modified attachments stands further away from the buccal surface of the tooth than does an ordinary bracket and band. A way to overcome this would be to make an all resin attachment with just an .022 metal rectangular slot embedded in it. This resin would be tooth colored so that a mouth full of these would be much more esthetic than a mouth full of steel brackets.

To demonstrate the problem of surface adaptation, the buccal surface of a stainless steel preformed band was cut away and to this piece of stainless steel an edgewise bracket was spot welded. A molar and bicuspid human extracted tooth were embedded in plaster. These attachments were bonded with 910 to the buccal surface of the teeth involved. The model was placed in water as usual and after two days, these attachments were easily dislodged. This pointed out that a metal surface of this type does not have enough intimate contact with the enamel surface to be of practical value.

It would seem that as the models soak in the water, the water molecules are able to insinuate themselves between the bonding material and the tooth surface, thereby breaking the bond. It remains to be determined through the use of dyes and/or radio active solutions the rate at which this takes place with different methods of attachment.

The fact that water molecules have a way of insinuating themselves between the faying surfaces, may be explained, partially at least, by the fact that the water molecules have an adhesive attraction to the enamel of the tooth, or resin, and thereby migrate their way continuously along the surfaces involved until the bond is eventually broken.

The fact that adhesion can be weakened or destroyed by water penetration between adhering surfaces was pointed out by VAN OLPHEEN[13]. It was calculated that a layer of water molecules penetrating between two unit layers of clay exerts a force of 2,000 atmospheres in separating the layers.

Investigation will have to be made to see whether it will be possible to seal the rim of the attachment area with some type of water impervious sealer, or whether it may be possible to modify the 910 to make it impervious to fluid migration.

In another report, BUONOCORE[3] told of the improved results in adhesion by the use of an inorganic siliceous filler with the cyano-acrylate in an approximate 1 : 1 ratio.

This mixture was placed in pits and fissures on teeth in the mouths of many patients in an effort to reduce caries. Most of the applications stayed in place over six months.

BUONOCORE[1] makes note of the fact that in industry, phosphoric acid and other preparations containing it are used to treat metal surfaces to get better adhesion. Therefore, he felt that perhaps an acid treatment of the enamel surface might render it more receptive to adhesion in the same manner that it does for metals. In his first method, he used a phosphomolybdate-oxalic acid treatment. A small drop of the molybdate agent was placed on the tooth surface and rubbed over it for thirty seconds. It

was then dried to a thin moist film. A drop of a ten per cent oxalic acid solution was applied directly over the area and rubbed in until a white precipitate formed, which was then air dried to form a white opaque surface. This surface was then flushed with warm water and rubbed with a cotton pledget. Using compressed air, the surface was then carefully dried just prior to application of a drop of acrylic filling resin. In the second method of surface treatment, eighty-five per cent phosphoric acid was used to accomplish the simple acid decalcification needed for adhesion. The method used was the same as above, except that the drop of acid was washed off with water after the thirty seconds contact with the enamel surface. After mechanical removal of the drops with both methods, the underlying enamel appeared as a sharply defined area of clean enamel which appeared white and opaque by contrast with the surrounding enamel. He states that in a few days the treated area of the whole enamel surface appeared normal again except for a faint loss of luster over the area of treatment. His work shows that the phosphoric acid treatment gives better results than the molybdate and is simpler to use. In his discussion, he points out that the increased adhesion obtained intra-orally on treated enamel surfaces may be due to several factors, such as :

1. *A tremendous increase in surface area due to the acid etching action.*
2. *The exposing of the organic framework of enamel which serves as a network in and about which the acrylic adheres.*
3. *The formation of a new surface due to precipitation of new substances ; for instance, calcium oxalate, organic tungstate complex and so on, to which the acrylic might adhere.*
4. *The removal of an old, fully reacted and inert enamel surface, exposing a fresh reactive surface more favorable for adhesion.*
5. *The presence on the enamel surface of an adsorbed layer of highly polar phosphate groups derived from the acid used.*

He also felt that such acid treatments are clinically safe. He supports this contention by noting the absence of any lasting noticeable effects on the enamel and by the knowledge that similar concentrations of phosphoric acid are used in phosphate cements. Treating of the surface with these acid preparations may result in adhesion which is purely a physical phenomenon. Also, the acids may increase the wetability of a surface ; allowing, therefore, better adhesion due to more intimate contact. He states that the use of an acid phosphate containing treatment material, which in addition to increasing surface area and wetability, also allows for the absorption of highly polar bonding to the acrylic. He goes on to say that this type of bonding would be much more desirable than one based solely on mechanical retention, in as much as it may be considered as a form of chemical union.

It seems that 910 produces a strictly mechanical, rather than physical bonding at the enamel surface. The hydroxy apatite crystal [7] has a formula of $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$. There is a layer of absorbed ions, such as $\text{Ag}(\text{OH})$, CO_3^- , HCO_3^- , PO_4^- , H_2PO_4^- , HPO_4^- , Mg , Ca , and citrate^- . Around this is a hydration layer and ion exchange takes place through the absorbed ion-layer, especially with the calcium in the core. It may be possible to modify the 910 to get bonding with some of these ions.

An investigation by SWANSON and BECK [12] also used Eastman 910 as the choice of bonding agent. They, also, used as an adheren a self-curing resin which they determined was not suitable. When confronted with the same moisture problem, they suggested that the significant reduction in bond strength in the presence of moisture did

not necessarily indicate a breakdown of what was adhered per se. This could be due, they say, to water sorption of acrylic resin which perhaps not only weakened the bond between the adhesive and acrylic resin, but, also, allowed moisture penetration to the total surface of the adhesive. They also did in vivo studies with 910 in the mouth and noticed no inflammatory or allergic reaction in 24 patients on which the material was used. It is further stated that this should not be construed to mean that the material is considered clinically safe. And it was pointed out that no claims were made by the manufacturer to this effect.

In their investigation[12], the uncured acrylic was placed against the Eastman 910 and a tooth surface. Also, the acrylic was painted on a piece of band material. This seems to present two problems;

1. *Some mixing of monomethacrylate with the 910 which might tend to weaken any bonding.*
2. *Not enough thickness of acrylic to eliminate areas of metal, 910, and tooth surface contact.*

In my investigation, I decided not to etch the tooth surface first with phosphoric acid because of criticism that some members of the profession have for this procedure. But how is more enamel lost? By etching and placing an attachment for some months and isolating the areas or by constant wear from tooth brushing and mastication during the same period of time? DOCKING, et al. [5], quote GASTELLO [4], who investigated the effect of zinc phosphate cement on enamel surfaces. They demonstrated that all enamel surfaces exposed to the action of various mixes of cement were more or less affected. The etching is more pronounced on a ground surface than on an unground one, and the cement liquid alone etched the enamel markedly and uniformly. The authors determined that in standard consistency of cement, no alterations in the surface of the tooth due to banding could be detected regardless of the cement used. Continually thinner and thinner mixes of cement were made and tested against enamel surfaces and actual breakdown of the surface could be detected only with the thinnest mix.

BUONOCORE [2] states very well the lines of investigation for determining the possibilities of bonding materials to tooth structure. These include:

1. *The development of new resin materials which have adhesive properties.*
2. *Modification of present materials to make them adhesive.*
3. *The use of coatings as adhesive inter-face materials between filling and tooth.*
4. *The alteration of the tooth surface by chemical treatment to produce a new surface to which present materials might adhere.*

As far as alteration of the tooth surface to improve adhesion is concerned, MATSUI and MINOGUCHI [8] described the treating of the surface with such compounds as vinyl-trisilane.

SWANSON and BECK [12] presented for orthodontic purposes, requirements for good bonding agents which are: (1) adhesiveness to tooth structure; (2) resistance to mouth fluids; (3) lack of toxicity to living tissue; and (4) a setting time practical for operating conditions.

To these should be added: (1) adequate shelf life of the agent; (2) the agent and attachment should be easily removed when desired with little or no alteration to the underlying tooth surface.

Summary

1. Eastman 910 was used as a plastic bonding agent to determine whether it could be used in clinical orthodontics to bond attachments directly to human enamel.
2. The greater the area contact between attachment and tooth surface, the longer the attachment will hold.
3. The greater the surface adaptation between attachment and tooth surface, the longer the attachment will hold.
4. Moisture eventually breaks the bond seemingly by fluid molecular migration between the faying surfaces.
5. Following the indirect method of fabrication, the attachments will give enough adhesion clinically to accomplish short procedures before the bond is broken ; at which time it may be re-attached if more time is needed.

Bibliography

- [1] BUONOCORE, M. G. : A Simple Method of Increasing the Adhesion of Acrylic Filling Materials to Enamel Surfaces. J. D. Research, **34** : 894, December, 1955.
 - [2] BUONOCORE, M. G. : Evaluation of Resin Film-Forming Materials for Use as Bonding Agents between Resin Filling Materials and Tooth Structure. J. D. Research, **34** : 749, October, 1955. Abstract.
 - [3] BUONOCORE, M. G. : Lecture, International Association for Dental Research reported in Dental Times, Vol. 8, Nos. 7 and 8, July. August 1965.
 - [4] CASTELLO, I., et al. : Effect of Zinc Oxyphosphate Cement on Enamel. American Journal of Orthodontics, **34** : 27, 1948.
 - [5] DOCKING, A. R., et al. : The Effect of Orthodontic Cements on Tooth Enamel. Dental Record, **72** : 243, October, 1952.
 - [6] Eastman 910 Adhesive : Eastman Chemical Products, Kingsport, Tennessee, TDR (technical data report) No. R-101.
 - [7] GOULD, B. : Lecture, March, 1960.
 - [8] MATSUI, A. and MINOGUCHI, G. : Experimental Study about the Adhesion to the Tooth Surface, J. D. Research, **42** : 754-755, May-June 1963. Abstract.
 - [9] ROSE, E., ERNEST, et al. : The Screening of Materials for Adhesion to Human Tooth Structure. J. D. Research, **34** : 577, August, 1955.
 - [10] SADLER, J. F. : A Survey of Some Commercial Adhesives : Their Possible Application in Clinical Orthodontics. American Journal of Orthodontics, **44** : 653, January, 1958. Abstract.
 - [11] SCHOUBOE, P. J., et al. : Resin Cements and Posterior Type Direct Filling Resins. J. D. Research, **52** : 584, May, 1956.
 - [12] SWANSON, L. T., and BECK, J. F. : Factors Affecting Bonding to Human Enamel with Special Reference to a Plastic Adhesive. Journal of American Dental Association, **68** : 551, November, 1960.
 - [13] VAN OLPHEN, H. : Adhesive Restorative Dental Materials, PHILLIPS, R. W. and RYGE, G. (ed), Spencer, Ind., Owen Litho Service, p. 9, 1961.
-