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The evolution of bonding in orthodontics

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In the early days of fixed-appliance orthodontic treatment, brackets were welded to gold or stainless steel bands. Before treatment, the orthodontist had to create enough space around each tooth to accommodate the bands, and then those spaces had to be closed at the end of treatment, when the bands were removed. This was time-consuming for the orthodontist and uncomfortable for the patient. Banded appliances frequently caused gingival trauma when fitted, and decalcification could occur under the band. In the mid-1960s, Dr George Newman, an orthodontist in Orange, New Jersey, and Professor Fujio Miura, chair of the Department of Orthodontics at Tokyo Medical and Dental University in Japan, pioneered the bonding of orthodontic brackets to enamel. Many developments have occurred in the decades that followed, including many new adhesives, sophisticated base designs, new bracket materials, faster or more efficient curing methods, self-etching primers, fluoride-releasing agents, and sealants. The purpose of this article is to review the history of orthodontic bonding, especially the materials used in the bonding process. (Am J Orthod Dentofacial Orthop 2015;147:S56-63)

From the inception of fixed-appliance orthodontic treatment, brackets traditionally have been welded to gold or stainless steel bands. The band encompassed the tooth circumferentially, requiring the creation of interproximal space to accommodate the width of the band material. This separation process, which was accomplished initially by placing wires and later elastomerics, was time-consuming for the orthodontist and uncomfortable for the patient. At the conclusion of treatment, these interproximal gaps had to be addressed again. In addition, banded appliances frequently caused gingival trauma when fitted, and decalcification under bands sometimes occurred during treatment. Therefore, the obvious solution to these problems was for the clinician to attach the brackets directly to tooth enamel, thus eliminating the need for bands.

Dr George Newman, an orthodontist in Orange, New Jersey, and Professor Fujio Miura, chair of the Department of Orthodontics at Tokyo Medical and Dental University in Japan, pioneered the bonding of orthodontic brackets to enamel. Coincidentally, they both began their experimentations in the mid-1960s. It is unfortunate that they lived on different continents, since they both had the same passion and vision—the development of an adhesive that would bond plastic brackets directly to enamel with enough strength to withstand the forces of occlusion during treatment, mastication, and archwire stress while allowing for biomechanical control and allowing for removal of the brackets without causing significant damage to the enamel. In addition, bonding had to be accomplished in a humid environment and needed to last from bracket placement through the final phase of treatment.

In the early 1970s, Miura[1] developed a technique for bonding polycarbonate plastic brackets to phosphoric acid–etched enamel using a restorative filling material developed by Masuhura et al,[2-4] also at Tokyo Medical and Dental University. The adhesive, Orthomite (Rocky Mountain Orthodontics, Denver, Colo), consisted of methyl methacrylate and polymethyl methacrylate with tri-n-butylborane as the catalyst. Miura found that the bond strength decreased with time as a result of exposure to oral fluids. In addition, mastication and abrasive metal archwires used with plastic brackets resulted in broken tie wings and deformed archwire slots. However, this system became popular as an alternative to bands and fueled the research to develop stronger adhesives and more durable plastic attachments, with an end goal of eventually developing bondable metal brackets. Other methyl methacrylate and polymethyl methacrylate systems followed from GAC International (Bohemia, NY) and TP Orthodontics (LaPorte, Ind) with the same successes and drawbacks.

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Submitted, revised and accepted, January 2015.
0889-5406/$36.00

http://dx.doi.org/10.1016/j.ajodo.2015.01.011

Newman continued his work with epoxy resins,[5] while Retief et al[6] from South Africa developed an adhesive to bond metal brackets, based on research conducted by Bowen on epoxy resins.[7] Epoxy resins did not experience significant polymerization shrinkage when setting, had the same coefficient of thermal expansion as enamel, and were cross-linked to minimize water absorption. These characteristics produced the strength needed to resist the inherent mechanical and masticatory forces. The final hurdle was increasing the strength of the brackets so that they could withstand the forces of 3-dimensional mechanics.

Retief et al partnered with 3M Unitek (Monrovia, Calif) to develop a mesh grid welded onto flattened stainless steel band material with a metal bracket welded to it. Strangely, this metal bracket/pad design was not available commercially until the late 1970s. The primary drawback to that design was that the weld spots on the mesh base prevented the adhesive from flowing between the mesh and the foil pad properly, resulting in reduced mechanical retention.

In the mid-1970s, Lexan plastic (General Electric, Fairfield, Conn) was used to fabricate anterior brackets for patients demanding better esthetics. This improved polycarbonate was harder and consequently less susceptible to wear and tie-wing fracture; however, it still was not as durable or reliable as stainless steel. Eventually, the continued demand for improved esthetics led to the development of ceramic materials for clear brackets. Ceramic was able to withstand forces, did not break or discolor, and still is a material of choice for appliances that are esthetically pleasing.

In the early 1970s, 3M Unitek's Concise and Adaptic from Johnson & Johnson (New Brunswick, NJ) were popular composite restorative filling materials, formulated from the research conducted previously by Bowen.[8] Both systems used a 2-paste bisphenol A glycidyl methacrylate (BisGMa) resin with quartz as a filler and amine-peroxide as the catalyst. These systems were cross-linked adhesives that experienced minimal polymerization shrinkage. Both systems required acid etching of the enamel with a 40% concentration of phosphoric acid. An unfilled resin then was applied to the enamel as a wetting agent, and the metal brackets were bonded to the conditioned enamel with a chemically cured paste.

At this time, metal brackets were welded to a perforated base (Fig 1). The adhesive became interlocked through the perforations to provide mechanical adhesion. The only complaint with perforated base brackets was that the adhesive covering the base through the perforations was affected by the oral environment so that it often became stained and discolored during routine orthodontic treatment.

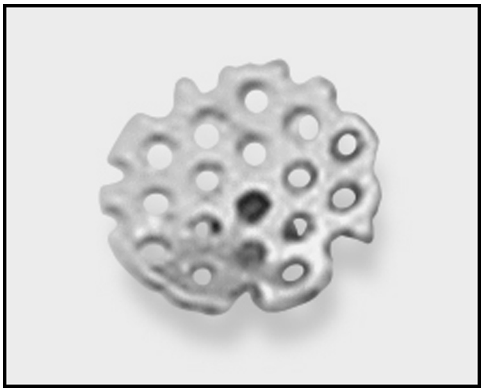

Fig 1. Perforated metal bracket base.

To bond chemically to the 2-paste epoxy resin adhesive, plastic brackets had to be coated with methyl methacrylate plastic conditioner before paste application. Several 2-paste chemically cured systems entered the marketplace shortly thereafter. In 1974, Dentsply/Caulk (Milford, Del) introduced the first single-paste ultraviolet (UV) light curable bracket adhesive, Nuva Tach; this system used a UV unfilled bonding resin (Nuva Seal) on the enamel and a single UV curable paste (Nuva Tach).

The paste and the unfilled resin were polymerized with light-emitting energy in the 280-nm range. These UV light-cured composites, like their chemically cured predecessors, originally were introduced as restorative materials with a slight modification in paste viscosity. Unlike the chemically cured systems, however, the UV light-cured system did not have working-time constraints. This characteristic allowed the clinician unlimited working time to place brackets, clean peripheral paste flash, and, if necessary, change bracket position before curing. However, the use of these UV light-cured systems was cut short when it was discovered that they were harmful to exposed skin and eyes, sometimes even resulting in burned soft tissues. Also, these UV systems used the perforated base metal brackets.

In 1975, while working at Lee Pharmaceuticals (South El Monte, Calif), I had an idea for a no-mix, chemically cured direct bonding system that would require the clinician to apply a liquid activator to the etched enamel and to the metal (or plastic) bracket base. A single paste would be applied to the primed bracket base that then would be placed on the tooth and pressed into position. The liquid activator from the enamel and bracket base mixed with the paste and resulted in polymerization. This system eliminated the mixing steps of Adaptic and Concise. The system yielded effective strength, but it depended on how well the bracket base fit the corresponding enamel surface. A flush fit produced the strongest bond. The chemistry