

# Orthodontics in 3 millennia. Chapter 16: Late 20th-century fixed appliances

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Ever since Edward Angle introduced his edgewise appliance in 1925, orthodontic innovators have been working to improve on not only its original design, but also the method of attachment. Our “strap-ups” have evolved from banding to bonding, from labial to lingual, and from metallic to clear. But, as Angle would be pleased to learn, we still call it edgewise. (*Am J Orthod Dentofacial Orthop* 2008;134:827-30)

**I**n Chapters 5 and 6, we learned that the ribbon arch (Angle), the edgewise (Angle), the twin wire (Johnson), the Begg, and the universal (Atkinson) were the principal types of brackets in the first half of the 20th century. Although this chapter will be confined to a discussion of the bracket (specifically the edgewise and its derivatives), the bracket does not exist in isolation from its system or technique (edgewise technique, universal technique, and so on). The orthodontic bracket’s sole purpose is to transmit forces from a traction device, usually an archwire, to the tooth. Thus, before the invention of enamel bonding, the 4 elements of an orthodontic appliance were the band, the bracket, the archwire, and the ligature. All the brackets in the following discussion are modifications of the original edgewise design.

## BRACKETS

### Rotation control

The narrow width of the original edgewise bracket limited its ability to control rotation. Soldering eyelets for this purpose was time-consuming in terms of both application and final result, but it was not until mid-century that 2 clinicians brought out different modes of replacing this chore.<sup>1</sup> On the East Coast, Brainerd F. Swain (1911-1999) attached 2 brackets to a single base and called it the twin, or “Siamese,” bracket. In Seattle, Paul D. Lewis (1896-1992)<sup>2</sup> soldered curved rotation arms, or “wings,” to a single bracket that contact the inside of the archwire. A modification of the Lewis bracket, designed by Howard M. Lang (1914-94),<sup>3</sup> uses straight arms with a hole to increase flexibility and for ligature tying. In both devices, the arms can be activated by a simple twist of the pliers. The principal

advantage of these winged brackets over the twin is that they do not reduce the interbracket span or impede the activation of closing loops.<sup>4</sup>

### Preadusted brackets

Several attempts at “building treatment into the appliance,” a phrase coined by Joseph R. Jarabak (1906-89),<sup>5</sup> were made in the first half of the 20th century. It was recommended by Angle<sup>6</sup> as early as 1928. Glendon Terwilliger was one of the first to attempt soldering brackets into tip and torque positions.<sup>7</sup> Holdaway (1952)<sup>8</sup> suggested that the brackets in the mandibular buccal segments could be angulated by an amount proportional to the severity of the malocclusion.<sup>4</sup> However, in 1959, Ivan F. Lee (1922-) (personal interview, June 25, 2007) produced a commercially viable torque bracket for anterior brackets, writing about it in his thesis for the American Board of Orthodontics. Lee Torque Brackets were marketed by Unitek (Monrovia, Calif) for about 15 years. At the 1960 AAO meeting, Jarabak, with James A. Fizzell, demonstrated the first bracket to combine torque and angulation.<sup>9</sup>

Another 12 years passed before Lawrence F. Andrews<sup>10</sup> (1929-) announced an appliance whose brackets were designed for each tooth so that, on being aligned on an unadjusted archwire, the teeth would assume ideal positions. Based on his “six keys to normal occlusion,” he called his design the Straight-Wire appliance (“A” Company, San Diego, Calif).<sup>5</sup> Building on the innovations of Lee and Jarabak, Andrews cut the appropriate amount of torque into each bracket and also angulated the bracket in relation to its base. It was the first bracket to combine torque, angulation, in and out, and offset (subsequently modified by Roth<sup>11</sup>). Unfortunately, the popularity of the term *preadjusted appliances* caused it to become the most commonly misused phrase in contemporary orthodontics. Every manufacturer touts its own straight-

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wire appliance system, regardless of prescription or specifications. Despite widespread use, experience with preadjusted brackets has shown that the goals of individual tooth positions are not always achieved with straight archwires only and require some wire bending to achieve ideal results.<sup>12</sup> Also, the term *straight*, as applied to an archwire, is really a misnomer. *Flat* or *level* would be more accurate.

Some claim that preadjusted appliances tend to produce transitional deepening of the overbite during leveling and aligning.<sup>13</sup> Kesling<sup>14</sup> maintained that preadjusted archwire slots set up more anchorage in the anterior teeth and makes space closure more difficult.

### Narrow slots

Although stainless steel had been in use in the early 1930s in band material and ligatures, it was not until 1953 that Steiner<sup>15</sup> brought out the first .018 × .022-in bracket to accommodate a like-dimension, stainless-steel archwire, greatly improving the elasticity (and comfort) of working wires.

### Esthetic brackets

In 1963, Morton Cohen and Elliott Silverman<sup>16</sup> brought out the first commercially available plastic brackets (IPB, GAC International, Bohemia, NY). The ceramic bracket was commercially introduced in 1987.<sup>4</sup> Ceramic brackets have some drawbacks: enamel damage during debonding, enamel cracking due to silane coatings on the base, and bracket wing fracture from the brittle nature of alumina. Plastic brackets also have drawbacks: distortion and color absorption. Both have greater frictional resistance than metal brackets. In the 1990s, these deficiencies were overcome with design modifications and the use of reinforced polycarbonate (for plastic) and polycrystalline alumina (for ceramic) and the addition of a metallic slot.<sup>17</sup>

### Bonded brackets

Direct bonding of orthodontic attachments was probably the most significant development in clinical orthodontics in the second half of the 20th century.<sup>18</sup> The first bonding agent for restorative dentistry, Sevriton Cavity Seal (Cavity Seal, London, United Kingdom), was formulated in 1949 by Oskar Hagger, a Swiss chemist working in London, using glycerophosphoric acid dimethacrylate, an unfilled acrylic resin.<sup>19</sup> In 1955, Buonocore,<sup>20</sup> borrowing the techniques of industrial bonding, enhanced the adhesion with the phosphoric acid etch.

Buonocore's work stimulated efforts to experiment with bonding orthodontic attachments to maxillary anterior teeth, but it was not until many years later that

a seemingly innocuous letter in the *American Journal of Orthodontics and Dentofacial Orthopedics* brought to light the answer to the question: which experimenter was actually the first to use a bonded bracket in treatment? The controversy began in 1990, when Herbert I. Cueto<sup>21</sup> wrote that his "direct-bonding technique was developed and used for the first time on several patients" in 1966 in the orthodontic department of the Eastman Dental Center, using a liquid monomer (methyl-2-cyanoacrylate) and a silicate filler.

Two years later, the February issue of the same journal carried 2 more "first-bonding" claims: David L. Mitchell,<sup>22</sup> in "The first direct bonding in orthodontia, revisited," and George V. Newman,<sup>23</sup> in "First direct bonding in orthodontia." Mitchell, a graduate student at the University of North Carolina in 1959, claimed that he had treated 5 patients using at least 1 bonded bracket; this became the basis for his master's thesis. He failed to report it in the literature because he was afraid of being expelled for using acid etch on humans.<sup>22</sup>

This reluctance kept direct bonding from being widely accepted by the specialty until the late 1970s. The matter was apparently put to rest when Newman<sup>23</sup> showed photographs of patients dating back to the 1950s in whom he had bonded clear acrylic laminates carved by hand from either Plexiglas (Rohm & Haas, Philadelphia, Pa) or polycarbonate rods, using a cold-cure acrylic-type (later, epoxy) adhesive.

### ADHESIVES MATURE

Since the middle 1960s, researchers have tried other materials to improve on Newman's acrylic, because, first, it could be used only on the maxillary anterior teeth; second, forces generated by rectangular wires caused many bracket failures; and third, too much time was involved in the cementing procedure.<sup>24</sup> The first bonding resins were 2-paste, chemical curing. In 1968, Smith<sup>25</sup> introduced a polyacrylate (carboxylate) (Durelon, 3M ESPE, St Paul, Minn). In 1970, Retief described an epoxy resin system designed to withstand orthodontic forces.<sup>26</sup>

As new adhesives, composite resins, and bonding techniques were introduced to restorative dentistry, orthodontists, always looking for innovations from other scientists, adopted some of these innovations for their bonding armamentarium. In 1962, bisphenol A glycidyl methacrylate (BIS-GMA) resins were introduced by Rafael Brown as dental adhesives and later applied in orthodontic practice.<sup>24</sup> These include Concise Ortho Adhesive, the first adhesive with a specific orthodontic formulation (1977) (3M Unitek); Nuva-Tach (Caulk, Milford, Del); and Pres-

tige and Restodent (both from Lee Pharmaceuticals, South El Monte, Calif). A mixture of BIS-GMA (a viscous liquid) with an aliphatic diacrylate (to make the adhesive more fluid) is now the most widely used resin.<sup>27</sup>

Improvements in composite resins included no-mix adhesives, altered filler packing, higher filler levels, and hybrid filler particles. These changes enhanced their mechanical properties, reduced the coefficient of thermal expansion, introduced radiopaque materials, reduced polymerization shrinkage, and improved esthetics.<sup>28</sup>

Initially used as a direct restorative material, glass ionomer cements (GICs) were invented in the late 1960s and developed in the early 1970s by Wilson and Kent,<sup>29</sup> becoming popular in the late 1980s for cementing bands. Whereas the resin-based adhesives depend on mechanical interlocking, GICs provide a chemical bond and set under moist conditions. GICs such as Ketac (3M Espe) and GC Fuji Plus (GC America, Alsip, Ill) are silicates of chiefly calcium and aluminum.<sup>29</sup> This material releases fluoride and thus might reduce enamel decalcification around brackets.<sup>30</sup> As such, GICs lack bond strength, but a newly developed, reinforced ionomer cement, or *compomer* (Fuji II LC, GC Dental Industrial, Tokyo, Japan), has been reported to exhibit no significant difference in failure rates compared with those using composite resin (System 1 Plus,Ormco, Glendora, Calif).<sup>31</sup>

During WWII, Harry Coover of the Eastman Kodak Company, while searching for a material for gunsights, discovered cyanoacrylate, the forerunner of Krazy Glue (Toagosei America, Jefferson, Ohio). During the Vietnam War, it was used to hold human tissue together. Today, higher molecular weight cyanoacrylates are used in liquid bandages.<sup>32</sup> A significant advantage of cyanoacrylate adhesives (Loctite, Loctite Corp, Rocky Hill, Conn) is their ability to polymerize as a thin film at room temperature with water as a catalyst.<sup>33</sup> Initially given poor marks, cyanoacrylate was found by Krishnan et al<sup>34</sup> to provide good bond strength if the material is kept in a 37°C water bath for 24 hours, even without enamel etching.

Using a methyl methacrylate (MMA) resin (Orthomite [now Super Bond, Morita, Tokyo, Japan]) with plastic brackets, Miura et al<sup>35</sup> were the first to present materials and techniques that have evolved directly into current protocol. Nuva-Tach was another early MMA adhesive. Further MMA adhesives to appear on the market included Ortho-Concise, Transbond (1987), and Transbond XT (replacing Concise, 1989) (all from 3M Unitek).

The acid-etched-composite technique has become the most widely adopted bonding system in contemporary orthodontic practice, but the system still has some shortcomings, such as loss of enamel after acid etching,<sup>36</sup> enamel damage caused by postdebonding cleanup,<sup>37</sup> and enamel fracture, particularly with ceramic brackets.<sup>34,38</sup> Siomka and Powers (1985)<sup>39</sup> and Newman et al (1995)<sup>40</sup> found that silanation (by Ortho-Cycle, Hollywood, Fla) improved the bond strength of new meshed brackets by as much as 21%.<sup>41</sup> Based on Rafael Bowen's use of a chelating agent, Sunmedical (Shiga, Japan) introduced Superbond, reported to prevent the risk of postdebonding enamel cracks. It also expanded bonding possibilities to metal, ceramic, and plastic brackets.<sup>42</sup> As a result, even molar bands, the last bastion of banding, began to face obsolescence.

The first study on light-curing appeared in 1979, but it was not until 1993 that the first commercial product came on the market (Transbond XT Light Cure, 3M Unitek).<sup>43</sup> That same year, Watanabe and Nakabayashi<sup>44</sup> developed a self-etching primer—an aqueous solution of 2% phenyl-P in 30% HEMA (hydroxymethyl methacrylate)—for bonding to enamel and dentin simultaneously.

More recent advances include flowable composite resins and condensable ones that behave clinically like amalgam. These resins have a higher filler load and improved filler matrix interface and handling properties.<sup>28</sup> In another attempt to save chair time with simpler bonding procedures, Unitek introduced adhesive-precoated brackets (APCs) in 1991. In addition to speed and accuracy, Cooper et al<sup>45</sup> listed the following advantages of APCs over conventional light-cured systems: (1) consistent quality and quantity of adhesive, (2) easier cleanup after bonding, (3) improved asepsis, (4) reduced waste during bonding, and (5) better inventory control.

It has taken half a century for orthodontic bonding procedures to evolve from acrylic to chemically cured (2-phase, then 1) to light-cured to dual-cured (chemical + light) to moisture-active to APCs. Even the device that threatens to replace conventional brackets altogether—the aligner—relies on bonded buttons, so it appears that some form of bonding will be with us for a while. Yet to come: the lingual bracket and the innovation second only to bonding in its impact on orthodontic bracketing: the self-ligating bracket.

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*Editor's note: This concludes the series of articles on orthodontic history.*

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