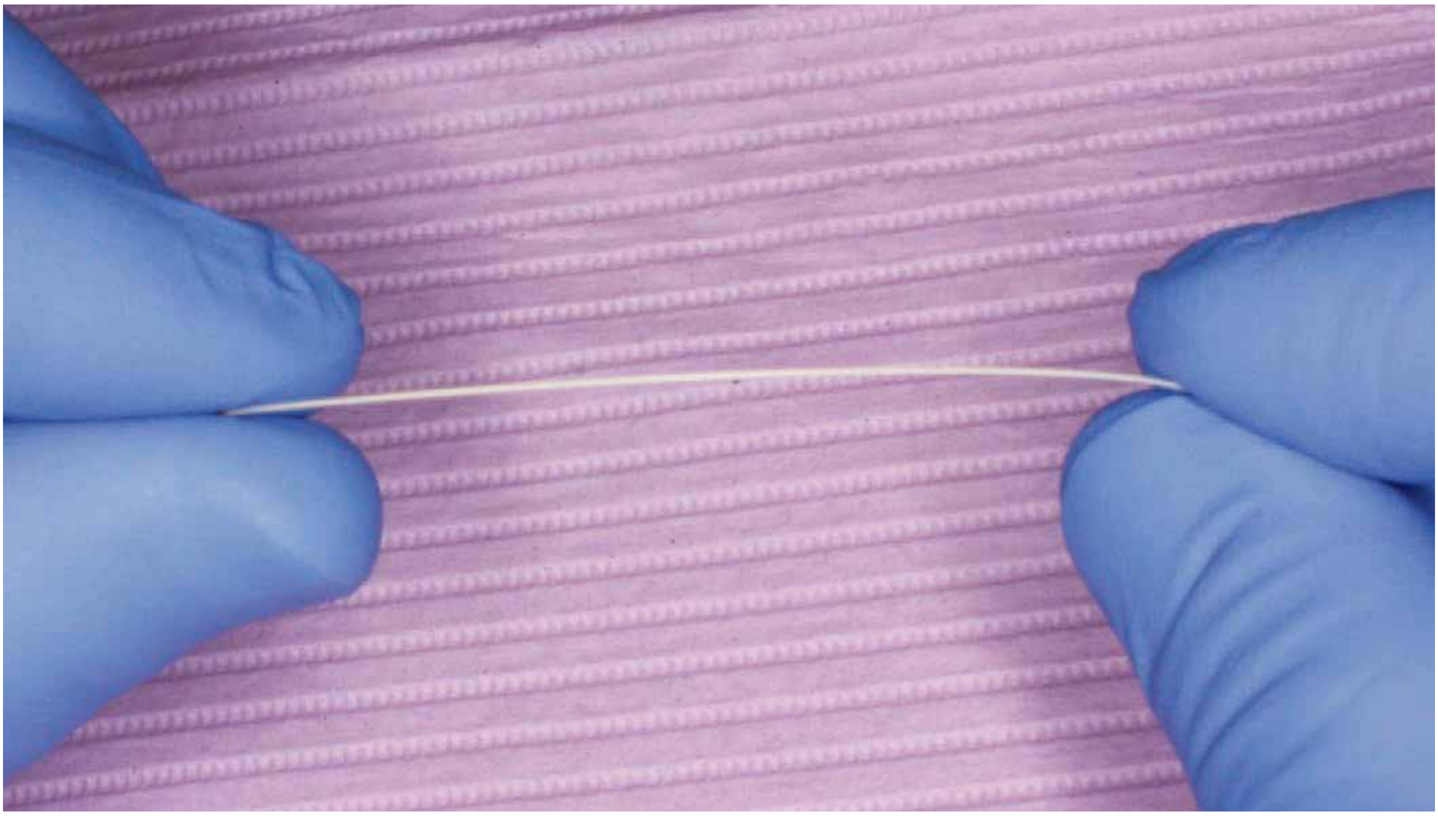

Figure 1: An 0.014-inch PTFE-coated FLI® Cu-NiTi wire (Rocky Mountain Orthodontics). The PTFE coating imparts an enamel hue. Despite the extremely low coefficient of friction of PTFE, the coating is applied only to the labial surface of rectangular wires to ensure the lowest frictional resistance.

Aesthetic Archwires

The evolution of aesthetic archwires to meet patient demands for invisible labial treatment

BY NEAL D. KRAVITZ, DMD, MS

Despite advancements in the aesthetics of clear orthodontic brackets, the appearance of orthodontic archwires has changed little. While increasing attention has been given to the use of aesthetically pleasing orthodontic archwires to complement clear brackets, these wires have not been routinely incorporated in treatment due to a lack of evidence-based research and practitioner familiarity, as well as concerns regarding fragmentation of the aesthetic coating and increased frictional resistance.

Currently, aesthetic archwires can be separated into two categories: (1) coated metal and (2) transparent nonmetallic. Each undergoes a distinct manufacturing process, resulting in unique challenges when used in treatment.

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Coated Metal Archwires

Coated metal archwires are nickel-titanium or stainless steel wires treated with a polytetrafluoroethylene (PTFE), epoxy-resin, parylene-polymer, or less commonly palladium covering to impart an enamel hue. Manufacturers vary with regard to the coating material, thickness of the coating, and steps within the application process to maximize aesthetics, flake-resistance, and mechanical efficiency. Currently, the two most common aesthetic archwires on the US market are coated with either PTFE or epoxy-resin.

PTFE, Teflon. PTFE, commonly recognized by the DuPont Co brand name Teflon®, is a synthetic polymer consisting wholly of carbon and fluorine. Due to the strength of the carbon-fluorine bonds, PTFE is nonreactive, heat-resistant, and hydrophobic. Most importantly, it has the third lowest coefficient of friction of any known solid, making it ideal for use as a nonstick coating for cookware, gears, plain bearings, or where sliding action of parts is needed.

PTFE coating is applied to an orthodontic wire by thermal spraying, a process in which finely heated materials are sprayed in a molten condition onto a surface to form a coating. Thermal spraying of PTFE onto an orthodontic archwire entails: (1) surface treatment of the wire by sandblasting (50-micron alumina) to support coating adhesion, (2) "masking" or covering with tape areas that are not be treated, (3) air-spraying atomized PTFE particles with clean compressed air to coat the wire, (4) baking in a chamber furnace to cure the coating onto the wire, and (5) removal of the masking tape. The PTFE layer adds a minimal thickness (.0008 to .001 inch) to the archwire.

PTFE-coated copper-nickel-titanium and stainless steel wires are supplied by Rocky Mountain Orthodontics as part of its aesthetic FLI® series of products. Though PTFE has an extremely low coefficient of friction, it is used primarily for aesthetic purposes. Round FLI wires have a three-quarter circumferential coating, and rectangular wires are coated only on the labial surface to reduce the effect on sliding mechanics (Figure 1, page 20, and Figure 2).

Epoxy-resin. Epoxy is a synthetic resin made by combining epoxide with another compound. Primarily recognized for its excellent adhesion, epoxies display a broad range of physical properties, such as chemical resistance, electrical insulation, and dimensional stability. They are widely used in orthodontic materials, including composite resins, molds, and polyurethane aligners.

Epoxy-resin coating is applied to an orthodontic archwire by electrostatic coating, or E-coating. Electrostatic coating is a process that uses electrostatically charged particles to more efficiently coat a workpiece. Electrostatic coating of epoxy resin onto an archwire entails: (1) applying a high-voltage electrostatic charge to the archwire, (2) applying an opposing electrostatic charge to the epoxy, (3) air-spraying atomized liquid epoxy particles to the wire, and (3) baking in a chamber furnace to cure the coating onto the wire. The epoxy coating does add a more significant thickness (.002 inch) to the archwire. Therefore, a .0180-inch NiTi wire becomes .020-inch diameter with an epoxy coating, or alternatively, the manufacturer may choose to use a smaller-diameter wire to compensate for the thickness of the coating.

Epoxy-coated nickel-titanium and stainless steel wires are supplied by G&H® Orthodontics as part of its Ultraesthetic™ series of tooth-colored archwires (Figure 3). The coating wraps around all sides of the wire and extends beyond the second molar.

The challenge with coating metal archwires is the lack of available metal primer. Metal primer allows better cohesion between the archwire and coating. All current metal primers contain toxins, and

Figure 2

Figure 3

Figure 4

Figure 2: High aesthetics of a PTFE-coated FLI® Cu-NiTi wire (Rocky Mountain Orthodontics) with FLI® ceramic twin brackets. Figure 3: Ultraesthetic™ NiTi archwires (G&H Wire). Figure 4: Silver primer surface treatment of the Vapor™ wire helps to adhere the thinner vapor-parylene coating.

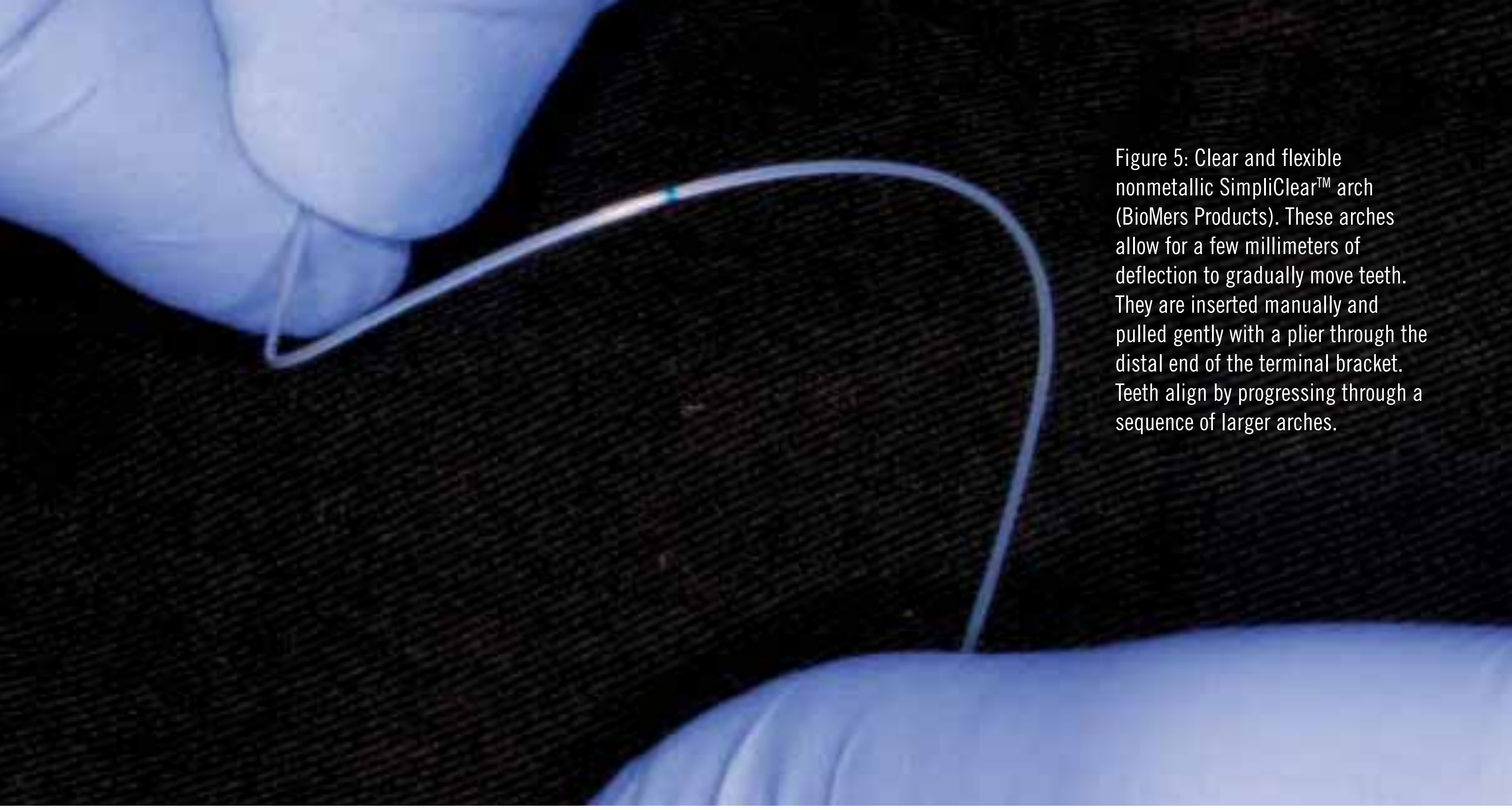

Figure 5: Clear and flexible nonmetallic SimpliClear™ arch (BioMers Products). These arches allow for a few millimeters of deflection to gradually move teeth. They are inserted manually and pulled gently with a plier through the distal end of the terminal bracket. Teeth align by progressing through a sequence of larger arches.

these primers do not have FDA approval for use in the mouth. As such, the coating often separates from the archwire due to mastication and activation of digestive enzymes. Research indicates that 25% of the epoxy coating is lost within the first month in vivo.[2] Recently, new vapor-parylene coated wires have been introduced, which use FDA-approved silver primer applied to the metal archwire to better secure a thinner aesthetic coating (Figure 4, page 22).

Transparent Nonmetallic Arches

Within the past 20 years, significant advancements have been made to create nonmetallic arches whose properties resemble metal alloys. Flexible nonmetallic arches are typically made from glass spindles embedded in a polymeric matrix. Some examples of nonmetallic arches include fiber-reinforced polymer (FRP)[3,4] or newer self-reinforced polymer (SRP).[5] These arches allow for a few millimeters of deformation and may be suitable for leveling and aligning in patients with Class I malocclusions with mild to moderate crowding (Figure 5). More importantly, they display the translucency and transparency ideal for ceramic brackets. Nonmetallic arches are not readily available. The most popular commercially available nonmetallic arch is SimpliClear™, made by BioMers Products LLC.

The manufacturing process for nonmetallic arches will vary depending on the type of polymer. Fiber-reinforced composite (FRC) orthodontic arches are made through a production process referred to as hot-drawing. Drawing is a working process that uses tensile forces to stretch a workpiece. Hot-drawing FRC arches entails: (1) melting of glass pellets, (2) spinning the glass into elastic and flexible fiber strands, (3) coating the fibers with a silane-coupling agent, and (4) coagulation of the glass fibers and methacrylate within an acetone solution.[3]

Disadvantages of Aesthetic Archwires

Coated metal archwires with circumferential coating deliver statistically lower loading and unloading force levels than uncoated wires of the same nominal sizes.[2,6] The lower force levels of coated wires may be attributed to: (1) the thick aesthetic coating having a negative effect on the load-deflection properties, or (2) a manufacturer's use of a smaller-diameter wire to compensate for the thick coating, particularly for epoxy-coated archwires. Additionally, the fragmentation of the coating adds increased frictional resistance and diminishes the aesthetic benefit.

Meanwhile, nonmetallic arches are brittle and allow for only moderate deformation. Excess deformation or forceful grip with pliers can lead to permanent deformation and irreversible cracks, referred to as "craze lines." These clear arches are restricted with regard to torque, detailing, and changes in arch width, and they are currently not suitable for patients requiring consolidation or anteroposterior correction. Despite the disadvantages of these commercially available nonmetallic arches, they provide an exciting first step for what's to come.

Conclusions

The growing demand for invisible orthodontic treatment has led to remarkable advancements in aesthetic archwire technology, from PTFE and vapor-parylene coating to nonmetallic fiber-reinforced polymers. These wires will continue to improve with regard to appearance, durability, and biomechanical control. Nonmetallic arches such as FRCs and SRPs are likely the future of aesthetic orthodontic wires, and they may someday replace traditional nickel-titanium and stainless steel wires in patients receiving ceramic braces. Orthodontists should consider incorporating aesthetic archwires into their practices to enhance the cosmetic experience of patients who desire invisible labial treatment. **OP**

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*References for this article are available with **Orthodontic Products'** interactive edition.*