Contemporary Esthetic Orthodontic Archwires – A Review

Jitesh Haryani[1], Rani Ranabhatt[2]

[1]Senior Resident, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, King George's Medical University, Lucknow, Uttar Pradesh, India
[2] Junior Resident, Department of Prosthodontics, Faculty of Dental Sciences, King George's Medical University, Lucknow, Uttar Pradesh, India

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Abstract

Growing demand of invisible braces by esthetically conscious patients has led to remarkable inventions in materials for esthetic labial archwires. Archwires with excellent optical clarity and mechanical properties comparable to conventional archwires have been manufactured by almost all the leading companies of orthodontic products in the past two decades, but their clinical use is still limited. Esthetic archwires can be divided into two main types, which are transparent non-metallic archwires (composite wires) and metallic wires with esthetic coatings. This article intends to provide an overview of various types of esthetic archwires available, and to gather evidence from the literature regarding their clinical applicability.

Keywords: Esthetic, Tooth colored, composite, coated archwire.

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Introduction

With increasing number of adult patients seeking orthodontic treatment, the demand for esthetic orthodontic appliances has increased dramatically, creating a need for the so-called invisible orthodontic appliances like Invisalign (1) and lingual braces (2). However, esthetics of fixed labial appliances has also evolved by inclusion of ceramic brackets[3], esthetic ligatures and tooth colored archwires. Attractiveness evaluation reveals that sapphire brackets with esthetic archwires are preferred just next to clear aligner trays.[4] to complement the esthetic brackets with invisible archwires, esthetic archwires have rapidly evolved in the last decade.(5).

Esthetic archwire materials are basically a composite of two materials which can be broadly classified into two major groups (5,6). (Fig. 1). The ceramic – polymer composite prototype of archwires are solid polymeric wires typically made from glass fiber spindles embedded in a polymeric matrix which are manufactured through a process called photo-pultrusion.(7). Goldberg et al (8). (1992) first reported the fabrication of fiber reinforced composites (FRC) using Bis-GMA resin and S2 glass fibers, but these wires were brittle and susceptible for intraoral breakage. Burstone et al[9] (2011) introduced a self-reinforced polymer (SRP) polyphenylene thermoplastic archwires which showed a flexibility comparable to NiTi and beta titanium archwires at thin cross sections without experiencing stress relaxation.

Coated esthetic archwires have a core of a metallic wire coated with either tooth-colored polymer (10, 11). or inorganic materials (12) to conceal the visibility of the underlying alloy and impart an enamel like hue to the archwire. Coating improves aesthetics, but creates a modified surface, which can affect friction, corrosive

Properties, and the mechanical durability of the wires. The coated wires are also found to be routinely damaged from mastication and activation of enzymes (Kusy, 1997) (7), due to which this coating has been described as 'undurable' (Proffit and Fields, 2002). (13).

Despite of advancements in wire technology, the clinical use of esthetic wires is still limited, probably due to lack of evidence based research and practitioner familiarity with these wires. So the purpose of this review was to compile the available data on various esthetic orthodontic wires and to analyze whether the properties of esthetic wires are comparable to conventional orthodontic archwires.

Materials and methods

A systematic review on this topic was not possible, as related articles were few and of varied origin; therefore, a literature search was conducted for peer reviewed articles published in English language. The systematic search was carried out for the keywords 'Esthetic', 'Tooth colored', 'Composite', 'Coated' and 'Archwire' from the year 1995 to October 2015 in Medline (PubMed) database. Articles retrieved from the electronic search were hand searched for the related references. The full text of all articles identified through the electronic and manual searches were reviewed and assessed for suitability. After applying the Boolean term "AND" for the keywords combinations Esthetic AND archwire; Tooth colored AND archwire; composite AND archwire; coated AND Archwire, a total of 95 articles were obtained. But after applying the following inclusion/exclusion criteria, eliminating duplicates, scrutinizing abstracts and full texts where necessary, only 22 relevant articles remained which were reviewed.

Inclusion Criteria

1. Both *in-vivo* and *in-vitro* studies were included
2. Studies exclusively on esthetic orthodontic archwires
3. Any type of study including randomized clinical trials, case control trials, review articles and descriptive studies were considered
4. Studies in English language only

Exclusion criteria

1. Studies on non-esthetic and ion implanted archwires
2. Studies on lingual orthodontic wires

A detailed search strategy and flow diagram showing selection of articles is illustrated in (Fig. 2)

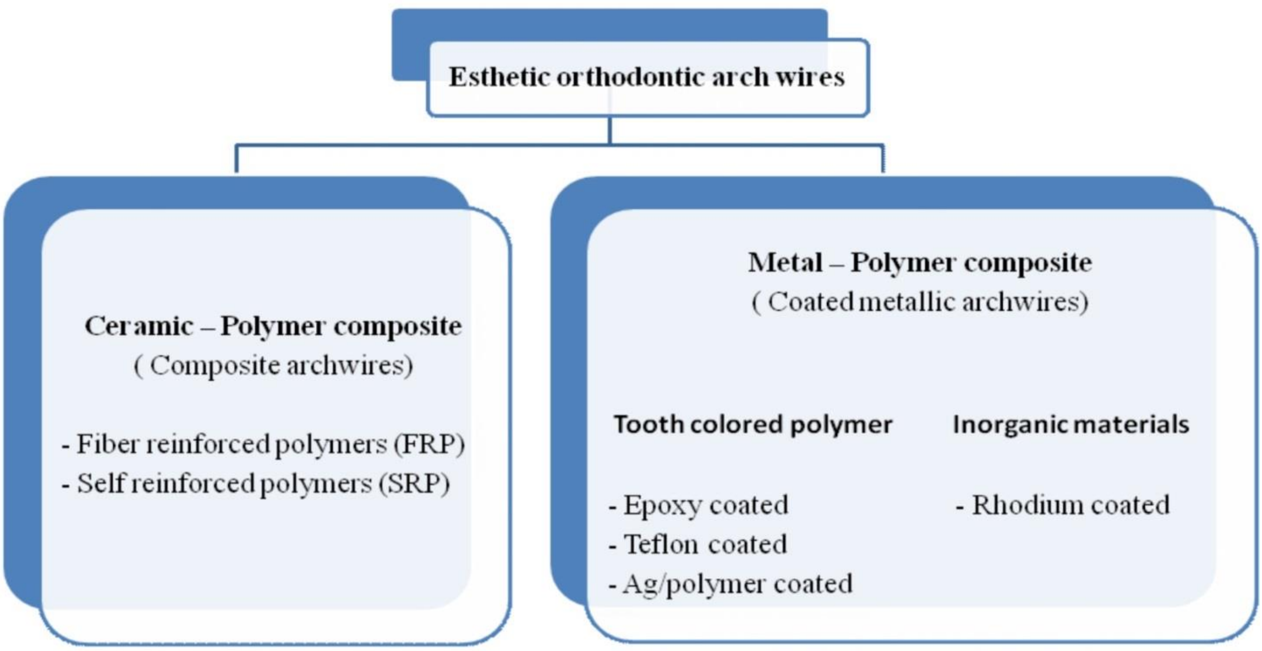

Figure 1: Classification of esthetic archwires

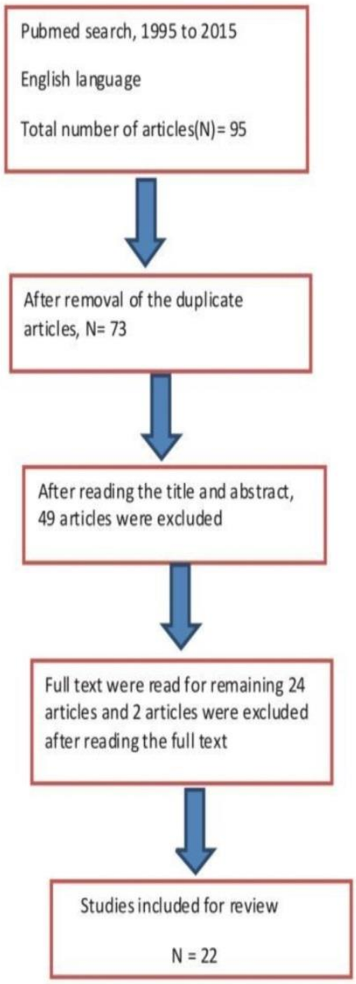

Figure 2: Systematic search strategy

Results

The final 22 articles comprised of 10 articles on composite wires and 12 articles on coated esthetic archwires; majority studies were *in-vitro* or *ex-vivo*, and there was no randomized clinical trial available on clinical efficiency of esthetic orthodontic archwires. Most articles focus mainly on mechanical properties and surface characteristics of esthetic archwires

Based on the review, experimental studies on fiber reinforced composite archwires show promising results for their application as esthetic alignment archwires. Bending or flexural properties of FRC wires was reported to be comparable to conventional NiTi archwire (14, 15, 16). Composite archwires possess higher sliding friction and surface roughness than stainless steel but comparable to conventional NiTi wires. (17, 18)

Properties of coated esthetic archwires vary according to the coating material used and the commonly used coating materials are Epoxy, Teflon, Ag/biopolymer and rhodium. Ryu et al (19). suggested that bending properties and surface roughness of epoxy resin coated archwires are better than other esthetic coated archwires; Epoxy coated wires deliver lower force level than other coated archwires (20,21). as well as conventional NiTi archwires of similar dimension (5,10,22). Although surface roughness of unused wire is least for Teflon coatings (23), but the sliding driven changes in surface morphology and increase in surface roughness of as retrieved wires are less in case of epoxy coated archwires. (24, 25). An important concern about the clinical applicability of coated archwires is the loss of properties on exposure to oral environment. Many authors have reported noticeable changes in surface properties and poor color stability after intra oral use (25, 26, 27).

Discussion

With rapid development in dental material science, the ongoing research on esthetic labial archwires is mainly focused on providing efficient orthodontic alignment. Esthetic archwires can be divided into two main types which are transparent non metallic archwires (composite wires) and metallic wires with esthetic coatings. The manufacturing process and properties of both types is entirely different, so they are separately discussed in this review.

The FRC archwires are esthetically pleasing because their translucent qualities tend to transmit the color of the host teeth. Zufall and Kusy (28). studied the visco-elastic properties of Bis GMA; TEGDMA composite archwires reinforced with S2 glass and concluded that the composite archwires retained sufficient resilience to function during initial and intermediate stages of orthodontic treatment. Huang et al (16) in 2003 introduced micromechanics bridging model based on tube shrinkage instead of the traditional pultrusion method to develop a new composite archwire and concluded that the mechanical performance of the prototype was comparable to that of metal Ni-Ti wire (ReflexR, TP Orthodontics Inc.) Similar results were found by Ballard et al (15). (2012) who reported that bending properties of FRC archwires were comparable to conventional NiTi wires.

Bending properties are affected by many factors like monomer composition of polymer matrix (29), curing method, environmental conditions like water storage (30) and even application of topical fluoride (31). Tanimoto et al (32) (2014) introduced glass fiber reinforced plastics (GFRP) composed of a polycarbonate matrix with glass-fiber reinforcement were fabricated for esthetic orthodontic wires using the pultrusion method. The GFRP wires had similar flexural properties to those of commercially available Ni-Ti wires. Toshihiro et al (33). (2015) evaluated the color stability of laboratory GFRP archwires and found that the GFRPs will maintain high color stability during orthodontic treatment.

Although esthetic composite archwires have a long history of experimentation, they were first commercially introduced in 2008 by BioMers Products as SimpliClear archwire, which has been developed from continuous fibers (E-glass fiber) and epoxy polymer matrix (tube shrinkage technique) and is currently marketed as the first completely clear archwire system for the treatment of mild to complex orthodontic cases

Chng et al (18). (2014) compared the sliding frictional properties of SimpliClear archwires to conventional NiTi wires with simulated wear and surface roughness using scanning electron microscope (SEM) and atomic force microscope (AFM). They found that FRC and NiTi wires show statistically comparable frictional wear when used with ICE, Gemini, Clarity, and SmartClip brackets

The second category of esthetic archwire materials is coated esthetic archwires, which differ according to the type of core metal used; i.e. either nickel-titanium or stainless steel and the esthetic coating used, which can be epoxy-resin, Teflon or polytetrafluoroethylene (PTFE), parylene or silver-polymer, rhodium or less commonly palladium. These archwires also vary based on the thickness of coating, area of coating (full coverage or labial surface only), manufacturing process and mechanical properties.

Epoxy resin is the most commonly used coating material because of its excellent adhesion, chemical resistance, electrical insulation, and dimensional stability. Epoxy coating is achieved by a method called as Electrostatic coating or E – coating in which a high voltage charge is applied to the archwire and atomized liquid epoxy particles are air sprayed over the wire surface. This gives a 0.002-inch thick epoxy covering around the wire. (34) Increased thickness of coating alters the mechanical properties of the wire due to reduced thickness of NiTi.

Polytetrafloroethylene coating is also commonly used material for esthetic coating. PTFE, which is 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. PTFE coating is done by a method called as thermal spraying in which atomized Teflon particles are used to coat the sandblasted wire surface using clean compressed air as a transport medium. This is further heat treated in a chamber furnace. PTFE coating has a thickness of 0.001 inch. Teflon coated esthetic archwires are supplied by Rocky Mountain Orthodontics (RMO) as FLI wire and Nitanium or tooth tone arch wire by OrthoOrganizer both have coating only on the labial side to decrease friction and thickness of coating.

Esthetic versions of the commonly used Sentalloy and Bioforce wires were developed by GAC in 2008 by Rhodium coating to be used with Inovation C self-ligating brackets, which have an active clip covered with rhodium.

Elayyan et al (5). Compared the load deflection properties of epoxy coated Ultraesthetic wires of 0.016 in and 0.018 × 0.025 in dimension (G&H wire) with non-coated wires of same dimension and same manufacturer. They found that Ultraesthetic coated archwires produced lower loading and unloading forces than uncoated wires of the same nominal dimensions. Kaphoor et al (22). (2012) compared load deflection properties of epoxy coated NiTi with same dimension of uncoated NiTi from 4 different manufacturers. They noted that aesthetic coated archwires delivered statistically significant lower loading and unloading forces than uncoated wires of same dimensions for Ultraesthetic (G&H), Spectra (GAC international) and plastic coated NiTi (Ortho Organizer), however no difference was found for Reflex esthetic wire (TP orthodontics). Similar results by Alavi et al (21). (2012)

Rudge et al (35) (2015) compared surface roughness and frictional resistance of fully coated, partially coated and rhodium coated 'aesthetic' nickel-titanium (NiTi) archwires with conventional NiTi and Stainless steel wires. They showed that coated archwires generally exhibited higher friction than uncoated controls. Choi et al (24). (2015) investigated the effect of sliding on surface properties of various esthetic NiTi wires (epoxy resin-coated, Teflon-coated, and Ag/biopolymer-coated) over stainless steel and ceramic brackets and suggested that epoxy resin-coated archwires were best for both esthetics and tooth movement when only considering surface roughness

Despite the well-known color stability of orthodontic appliances such as brackets and ligatures, the color stability of esthetic orthodontic wires is poorly understood. The color of coated archwires tends to change over time, the coating splits by exposing the underlying metal (6, 10, 26). Type of coating material and its surface roughness play decisive roles in the extent of the discoloration. Color changes can be examined using the CIE L*a*b* color system. This system is one of the most popular and universally used systems for dentistry. Most authors have suggested that there is deterioration of color and increased surface roughness of coated archwires after their use. (25, 36). Elayyan et al (10). (2008) observed that retrieved epoxy coated Ultraesthetic archwires (G&H) showed discoloration, ditching, and delamination and only 75% of the coating was present and 25% of the coating was lost within 33 days in vivo. da Silva *et al*[27] stated that all esthetic archwires assessed in their study showed noticeable color changes after 21 days in staining solutions. Coated wire NiTi (Trainerio, Rio Claro, SP, Brazil) and tooth tone plastic coated (Ortho organizers, Sao Marcos, Calif) wires showed less color change

Conclusion

With growing demand of esthetic orthodontic appliances, the need for tooth colored archwires with better appearance, physical properties and durability is the present challenge to manufacturers; and more in vivo studies of these archwires are needed. Till now, there is no evidence of any single esthetic archwire being clinically superior to conventional archwires being used is available. Fiber reinforced composite archwires with newer types of polymers can be the future of esthetic archwires and might completely replace the conventional metallic archwires.

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Corresponding Author:
Jitesh Haryani
Senior Resident, Department of Orthodontics and Dentofacial Orthopaedics,
Faculty of Dental Sciences, King George's Medical University, Lucknow, Uttar Pradesh, India
E-mail: jiteshkgmu27@gmail.com
Mobile: +918400155876