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Advances in orthodontic archwires

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***Abstract*---**Recent advances in orthodontic wire alloys have resulted in a varied array of wires that exhibit a wide spectrum of properties. Up until the 1930s, the only orthodontic wires available were made of gold. Subsequently, stainless steel was introduced and due to its superior properties gained popularity over gold. The introduction of nickel-titanium archwires revolutionized the orthodontic field with their shape memory & superelasticity. Several other alloys with desirable properties have been adopted in orthodontics. These include cobalt-chromium, beta titanium and multi-stranded stainless steel wires. The availability of archwires with widely diverging properties has profound implications on appliance mechanics and can be used to advantage at different stages of orthodontic treatment. The newer archwires score over conventional wires in terms of efficiency, total treatment time, and finishing. Also, the current emphasis on esthetic treatment options in orthodontics has led to the development of esthetic archwires. Presently the orthodontist may select, from all the available wire types, one that best meets the demands of a particular clinical situation. The selection of an appropriate wire size and alloy type in turn would provide the benefit of optimum and predictable treatment results. The purpose of this paper is to review current orthodontic archwires including recent advances.

***Keywords*---**archwire, nickel-titanium, esthetic archwire.

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Introduction

Orthodontic therapy is a force management procedure largely based on use of arch wires for storing and distributing biologically tolerable forces by means of which position of teeth is altered[1-3]. Earlier, gold was most commonly used as orthodontic wire. Gold archwires were expensive and were replaced by the introduction of stainless steel in 1929. In the period prior to seventies, stainless steel were commonly used since they are inexpensive and had improved mechanical properties. In the mid seventies, nickel-titanium and a host of other materials such as cobalt-chromium, beta-titanium and multi stranded stainless steel wires were developed. The introduction of nickel-titanium in particular revolutionized the orthodontic profession. The demand for an optimum, predictable and effective force system lead to development of many newer orthodontic archwires with extensive range of properties due to the advancements in material technology.

The development of an appliance combining both esthetics and efficiency is the ultimate goal for a successful orthodontic practice in the present era. Due to the significantly increasing demand for esthetics both by younger generation as well as adults during fixed appliance therapy, esthetic brackets have been introduced. The advent of esthetic brackets in orthodontics created a need for esthetic arch wires. There are newer wires presently available in the market that deliver optimum forces to teeth which results in minimal patient discomfort, reduced span of treatment and minimal clinical appointments[4]. Some of the newer arch wires available include supercable, copper- NiTi, timolium wire, optiflex archwire, bioforce wire, fiber reinforced composite archwire, teflon coated stainless steel wires and marsenol

The Chronological Development of Archwires

Evans (1990) divided the phases of archwire development into five phases[5]

PHASE	Method of force delivery	Force/Deflection characteristics	Material
PHASE I	Variation in archwire dimension (e.g. diameter, length)	Linear force/deflection charachteristics	Stainless steel, Gold
PHASE II	Variation in archwire material but same dimension (e.g. variable modulus orthodontics, Burstone 1981)	Linear force/deflection characteristics	Beta Titanium, Nickel titanium, Stainless steel, Cobalt chromium
PHASE III	Variation in archwire diameter	Non-linear force deflection characteristic due to stress induced structural change	Superelastic Nickel Titanium
PHASE IV	Variation in structural composition of	Non-linear force/deflection	Thermally activated Nickel

	archwire material	characteristic dictated by thermally induced structural change	titanium
PHASE V	Variation in archwire composition/structure	Non-linear force/deflection characteristics dictated by different thermally induced structural changes in the sections of the archwire	Graded, thermally activated Nickel titanium

Newer Orthodontic Archwires

Chinese NiTi

Chinese NiTi was developed originally by Dr. Hua Cheng Tien and colleagues at research institute for non-ferrous metal in Beijing (China) in 1978. Chinese NiTi wires possess superelasticity and shape memory. At mouth temperature, this wire is work hardened martensite and hence does not rely on shape memory characteristics in clinical applications. It's very high springback and low stiffness characteristics have won wide clinical acceptance for initial tooth alignment. The stiffness of this wire is 73% that of stainless steel wires and 36% that of conventional nitinol. It can be deflected 1.6 times as far as nitinol wire or 4.4 times as far as stainless steel wire without appreciable permanent deformation[6,7]. It has a high range of action and spring back properties. Chinese NiTi is applicable clinically where large defection for uprighting, labial and lingual tooth movements is needed.

Japanese NiTi

In 1978 Furukawa Electric Co. Ltd. of Japan discovered a new type of NiTi alloy which was reported by Miura et al in 1986[8]. Japanese Niti is austenitic active NiTi alloy. It displays superelasticity which is achieved by stress-induced martensitic transformation (SIM)[9]. Clinically they provide light continuous force for physiologic tooth movement and greater patient comfort. Japanese NiTi is marketed as Sentalloy[10].

NeoSentalloy

They are new superelastic NiTi and rectangular wires. They can be used with extremely light force in the initial phase of treatment rather than using round wires in the initial treatment. Three-point bending and torque tests have shown the wire to exert light, continuous force regardless of deflection or wire size[11]. Its advantages include good three-dimensional tooth control which can effect horizontal, vertical leveling and root torquing at the same time.

Copper NiTi

Copper NiTi was developed by Rohit Sachdeva and Suchio Miyasaki in 1994. They represent the next generation of both superelastic and shape memory wires by reducing hysteresis and by providing precise transformation temperature. When compared to conventional nickel titanium wires copper NiTi develops approximately 20% less loading force[10]. This permits easier engagement in the bracket slot since the wire can be manipulated with less difficultly and it creates less trauma and discomfort to the patient.

The addition of copper to the NiTi allows for programming precise transformation temperature characteristics during the manufacturing process. This built-in precision puts the clinician in control especially during the early stages of treatment. Cu NiTi archwires are set at four transformation temperatures for four distinct force levels, enabling clinicians to deal with specific clinical situations and are classified as follows:

- *Type I (15°C):* It is not used frequently in clinical situations because it generates very heavy forces and clinical indications are few.
- *Type II: (27°C)*
- *Type III: (35°C)*
- *Type IV: (40°C)*

The characteristics & indications of Cu NiTi archwires is summarized in Table 2

TYPE II (27°C)	TYPE III (35°C)	TYPE IV (40°C)
Useful in mouth breathers	Activates at normal body temperature	Activate after consuming hot foods & beverages (T> 40°C)
Generates higher forces	Generates forces in mid-range	Generates intermittent forces
Patients with higher pain threshold	Patients with normal pain threshold	Patients who are sensitive to pain
Normal periodontal health	Normal to slightly compromised periodontium	Compromised periodontal conditions
Rapid tooth movement is required	When relatively low forces are desired	Where tooth movement is deliberately slowed down e.g. when the patient may not be able to visit the orthodontist regularly, or the co-operation is very poor

Table 2: Characteristics of Cu NiTi archwires

Super Cable Archwires

Super elastic nickel titanium coaxial wire known as 'supercable' introduced by Hansen in 1993 united the mechanical advantages of multi stranded cables and the properties of super elastic archwires. These comprise of seven individual strands that are woven together in a long gentle spiral to maximize flexibility and minimize force delivery[12]. (Figure 1)

Advantages

- Improved treatment efficiency,
- Elimination of archwire bending, flexibility,
- Ease of engagement regardless of crowding,
- Light continuous force eliminating any adverse response of the supporting periodontium,
- Minimal patient discomfort after initial archwire placement and
- Fewer patient visits due to longer archwire activation periods[13].

Disadvantages

- The wire ends have a tendency to fray if not cut with sharp instruments
- Tendency of wires to split and untangle in extraction spaces, inability to create bends, steps, or helices and
- Tendency of wire ends to migrate distally leading to soft tissue irritation as the teeth begins to align[14].
-

Figure 1: Supercable Archwire

Biotwist Niti Archwires

They are 0.021"x 0.025" preformed rectangular archwires. They are formed with multiple strands of titanium superelastic wires (Figure 2). They display low force and low stiffness along with excellent flexibility [15]. The rectangular shape allows significant engagement of the slot. Bio twist wires have been indicated for use at the beginning of treatment during the leveling and aligning while also controlling torque.

Figure 2: Biotwist Archwire

Bioforce (Graded Thermodynamic NiTi/ TriForce) Archwires

They were introduced by GAC International (New York, United States). They are aesthetic and belong to the first and only family of biologically correct archwires. They are graded thermodynamic nickel titanium archwires. These wires can produce variation in archwire force by variable transition temperatures along the length of the wire[16]. Variable heat treatment of the wire allowed a single wire size to have three different force levels. The optimal super elastic wire now offered light forces in the anterior section (80 g), medium force in the bicuspid area and a heavier force (300g) in the molar region (Figure 3).

Figure 3: Bioforce Archwire

Bioforce with Ionguard Archwires

For reducing the frictional resistance, GAC International (New York, United States) created a nickel-titanium wire subjected to an ion implantation process without affecting the unique superelastic properties of BioForce. At low temperature, a high energy beam of ions is used to modify the surface structure and chemistry. Ion implantation improves wear resistance, surface hardness, resistance to chemical attack, and most importantly reduces friction. These archwires showed a smoother surface and generated less frictional force compared to untreated NiTi[17].

Smartarch Multi-Force Super-Elastic Archwires

SmartArch is a new generation of multi-force laser conditioned Copper NiTi wires. These wires were discovered by Dr. W. Eugene Roberts, Dr. Jeffery A. Roberts, Dr. Stephen Tracey and Dr. David M. Sarver. Its properties are based on the optimal compressive stress in the periodontal ligament (PDL) to achieve rapid tooth movement with minimal necrosis and patient discomfort[18]. Wires are programmed to deliver an ideal physiologic load on each tooth based on each tooth's PDL compressive stress value. They are available in a 0.016" round and 0.018" x 0.025" rectangular configurations (Figure 4).

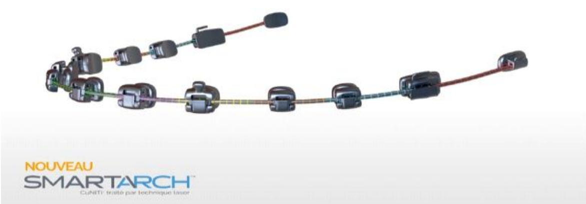

Figure 4: Smartarch Multi-force Archwire

Orthocosmetic Elastinol Archwires

These were manufactured by Masel Orthodontics (Carlsbad, United States). They are epoxy coated, esthetic high performance NiTi superelastic archwires that blend exceptionally well with ceramic or plastic brackets (Figure 5). They don't stain, discolour, and also resist cracking or chipping[19].

Figure 5: Orthocosmetic Elastinol Archwires

Marsenol Archwires

Marsenol is a tooth coloured nickel titanium wire (Figure 6) manufactured by Glenroe technologies (Florida, United States). They are elastomeric poly tetra fluroethyl emulsion (PTFE) coated nickel titanium archwires. It exhibits all the same working characteristics of an uncoated superelastic nickel titanium archwires[20]. The coating adheres to the wire and remains flexible. They deliver constant force over long periods of activation and are fracture resistant.

Figure 6: Marsenol Archwire

Nitanium Tooth Toned Archwire

They are superelastic NiTi wires marketed by Ortho Organizers Organizers (Carlsbad, United States). They have special plastic and friction-reducing tooth coloured coatings that blend with natural dentition, ceramic, plastic, and composite brackets, and maintain their original colour (Figure 7). These wires deliver gentle force but the coated white coloured wires have shown to succumb to forces of mastication and enzyme activity of the oral cavity. They are available in round 0.014", 0.016", 0.018" and rectangular 0.016" x 0.022" sizes[19].

Figure 7: Nitanium Tooth Toned Archwire

Nitinol total control (NTC)

Nitinol Total Control (NTC) is a new pseudo-superelastic nickel titanium alloy. They accept specific first, second, and third order bends while maintaining its superelastic properties. NTC combines the ability of superelastic NiTi to deliver light, continuous forces with the flexibility required to account for variations in the arch form [21]. It reduces the archwire inventory without compromising treatment mechanics. The number of archwire changes required is less, thus NTC allows the clinician to treat more patients effectively and efficiently. They display low stiffness and its properties are not temperature dependent.

Memotain

Memotain is a CAD CAM fabricated lingual retainer, made of 0.014” x 0.014” rectangular nickel titanium (Figure 8). The wire is highly flexible and custom cut to precisely adapt to the patient’s lingual tooth anatomy. It was introduced in 2012 by an orthodontist Pascal Schumacher. The name memotain is a portmanteau from the combination of ‘memory’ and ‘retainer’ because of the uniqueness of using nickel titanium for the lingual wire[22].

Figure 8: Memotain lingual retainer

Dual Flex Archwires

The anterior portion is made of titanal and posterior part is of stainless steel. Titanal is a nickel titanium alloy manufactured by Lancer Pacific (Figure 9). Three types are available:

The Dual Flex-1

It consists of an anterior section made of 0.016” round titanal and a posterior section made of 0.016” round steel. At the junction of the two segments, cast ball hooks are present mesial to the cuspids. The flexible front part easily aligns the anterior teeth and the rigid posterior part maintains the anchorage and molar control by means of the “V” bend, mesial to the molars. It is used at the beginning of treatment. They are very useful with the lingual appliance, where anterior inter bracket span is less[23].

The Dual Flex-2

It consists of a flexible front segment composed of a 0.016” x 0.022” rectangular titanal and a rigid posterior segment of round 0.018” steel. The rectangular anterior titanal segment when engaged in the bracket slots impedes movement of the anterior teeth, while closing the remaining extraction sites by mesial movement of the posterior teeth[23].

The Dual Flex-3

This consists of a flexible anterior part of a 0.017” x 0.025” titanal rectangular wire and a posterior part of 0.018” square steel wire. The Dual Flex-2 and 3 wires provide anterior anchorage and control molar rotation during the closure of posterior spaces. They also initiate considerable anterior torque[23].

Figure 9: Dual-Flex Archwires

Beta Titanium Wires (TMA)

Beta titanium wire was developed by Dr. CJ Burstone in 1980. It is commercially available as TMA (Titanium-molybdenum alloy). Beta titanium has a modulus of elasticity that is less than that of stainless steel and about twice that of Nitinol. This makes its use ideal in situations in which force less than those of stainless steel are necessary and in instances in which a lower modulus material such as Nitinol is inadequate to produce the desired force magnitudes. It is possible to attach stops, hooks, and active auxiliaries by welding to beta- titanium wires, thereby increasing the versatility of the wire[24].

With half the force but twice the working range of stainless steel, TMA has indications for all stages of treatment. In the initial stages, TMA is recommended for tooth alignment & space closure. In the intermediate stages, TMA is recommended for early torque control with moderate forces. In the final stage of the treatment, TMA is used as a detailing wire with moderate force.

Reverse Curve TMA

TMA with reverse curve of Spee is ideal for bite opening, arch leveling, space closure and early three-dimensional manipulation and torque control. In addition,this arch wire provides the mechanics necessary for leveling deep bites and countering undesirable tipping tendencies during space closure.

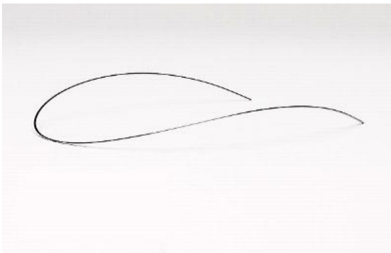

Figure 10: Reverse curve TMA

Titanium Niobium Wires

It was introduced in early 1995 by Dr Rohit Sachdev. Ti- Nb is soft and easy to form, yet it has the same working range of stainless steel. Its stiffness is 20% lower than TMA and 70% lower than stainless steel. Ti-Nb wires have a larger plastic range, similar activation and deactivation curves and relatively low spring back. Its bending stiffness is 48% lower than that of stainless steel and spring back 14% lower than that of stainless steel. It is easy to make creative bends and avoid excessive force levels as compared to a steel wire[25].

Timolium Archwire

This is also called Alpha – beta titanium alloy, manufactured by TP Orthodontics[14]. These archwires combine the flexibility, continuous force and spring back of Ni-Ti with the high stiffness and bendability of stainless steel wire. Titanium is the major constituent of Timolium with aluminum and vanadium as stabilizing agents. The composition is 85% or more Ti, 6.8% Al and 4.2% V. Aluminum stabilizes the alpha phase of titanium to room temperature, whereas vanadium stabilizes the beta phase.

Surface evaluation by scanning electron microscopy has revealed a smooth surface with little surface irregularity for Timolium archwires reducing the friction to a great extent. Though stainless steel with high values for strength, low friction, and smooth surface continues to be most commonly used archwire in orthodontic therapy, Timolium with its smooth surface, reduced friction, low modulus, and better strength could be also considered as a breakthrough in clinical orthodontic practice[26].

Azurloy (preformed and straight)

Azurloy is a heat-treatable alloy with excellent formability in its non-treated form. Applications that take advantage of this formability, followed by heat-treating to increase the spring rate, might include:

- Multiple-loop systems
- Utility arches
- Overlay intrusion or Base Arches

Drift Free Archwires

A built in 1 mm midline stop prevents lateral arch wire shift. The shifting of arch wire might injure the buccal mucosa on one side and the wire is out of the buccal tube on the other side. The permanent midline stop also acts as a reference point where measurements can be taken easily. Many times the mark or the spot to demarcate the midline wears off.

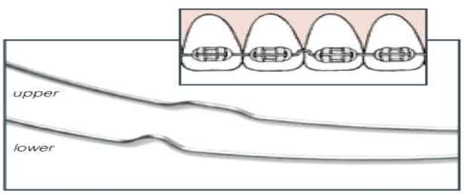

Figure 10: Drift free archwires

Fiber Reinforced Composites (FRCs) Archwires

Fiber reinforced composite arch wires are fabricated using a procedure called pultrusion. Fiber bundles are pulled through an extruder, in which they are wetted with a monomer resin. Then the monomer is cured with heat and pressure resulting in polymerization. Circular or rectangular wires are formed during curing. This may be shaped into a different morphology by further curing, a process known as beta staging. For this, the monomer should initially only be partially cured. The composite archwires have higher coefficients of friction than stainless steel but lower coefficients than either Nickel-titanium or Beta-Titanium. At high forces and angulations abrasive wear of the composite surface at the archwire-bracket interface was observed. It can lead to release of glass fibers within the oral cavity, which is unacceptable[8].

Advantages of fiber reinforced composite wires include excellent combination of high elastic recovery, high tensile strength, low weight, excellent formability, excellent esthetics because of their translucency, ability to form wires of different stiffness values for the same cross section which would facilitate the practice of constant cross-section orthodontics. Attachments can be directly bonded to these wires, which eliminate the need for soldering and welding. It is a safer choice for patients with nickel allergy[15,27].

Burstone and Kuhlberg introduced a new fiber reinforced composite called "Splint-It" which has S2 glass fibers in a bisGMA (bisphenol-A glycidyl methacrylate) matrix[28]. Various configurations such as rope, woven strip and unidirectional strip are available. These materials are only partly polymerized during manufacture, which makes them flexible, adaptable and easily contourable over the teeth. Later they are completely polymerized and can be bonded directly to teeth. It may be used for post treatment retention, as full arches or sectional arches, and to reinforce anchorage[16].

Conclusion

Recent advances in orthodontic wire alloys have resulted in a varied array of wires that exhibit a wide spectrum of properties. Knowledge of material science & properties of orthodontic wires enables professionals to choose the best possible archwire for specific treatment protocols. Appropriate use of these wires may enhance the patient comfort; reduce the chair side time and duration of the treatment. Though superior materials and techniques are now available and many replace conventional methods, still no single arch wire is ideal or best for all stages of treatment. Since arch wires are the main force system in orthodontics, knowledge about newer arch wires will help us to select the appropriate wire within the context of their intended use during treatment. With rapid progress in science & technology today, archwires will continue to evolve & surely result in significant improvements in archwires in the future.

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