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REVIEW

Which Orthodontic Wire and Working Sequence Should be Preferred for Alignment Phase? A Review

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ABSTRACT

The key to a successful orthodontic therapy depends not only on manual skills and knowledge about treatment steps, but also on knowledge and choice of materials used. One of the major components of fixed orthodontic therapy is the choice of wires. Orthodontic wires are defined as devices consisting of a wire conforming to the alveolar or dental arch, used as an anchorage in correcting irregularities in the position of the teeth. The history of these materials is as old as that of fixed orthodontic treatments and they present different features. With proper general knowledge, doctors can differentiate between wires and use the sufficient wire sequence suitable for each patient. This can increase the quality of treatment. Therefore, the aim of the present review is to focus on the differences in features of wires as well as the sequence of leveling wire selection according to the treatment plan.

Keywords: Orthodontic wires, sequence preference, alignment

INTRODUCTION

A successful orthodontic therapy depends not only on manual skills and knowledge of treatment steps but also on knowledge and choice of materials used. One of the major components of fixed orthodontic therapy is the choice of wires. Orthodontic wires are defined as devices comprising a wire conforming to the alveolar or dental arch, which is used as an anchorage for correcting irregularities in the position of teeth (1). The history of this material is as old as that of fixed orthodontic therapy, and wires present different features. Therefore, the aim of the present review was to focus on the differences in the features of wires as well as their working sequence according to the treatment plan.

History and General Properties of Different Orthodontic Archwires

In 1887, the father of orthodontics Edward Angle used nickel–silver alloy wires for his initial practice (2). Subsequently, as he kept experimenting with different materials such as copper, nickel, and zinc alloys, his favorite material became 14-18 karat gold. Until the early 1930s type IV gold alloys comprised the most widely used material for wire manufacturing (2). Gold alloys are not used in routine orthodontic therapy anymore because they are expensive and not esthetic. However, at times, when patients are allergic to other metals, the use of gold is considered (3).

In 1929, stainless steel (SS) was introduced in the field of orthodontics. It was manufactured by a German company and promised greater resilience than gold. SS was claimed to be less likely to break under stress. In addition to the mechanical advantages of SS, it was cheaper than gold; therefore, it started becoming increasingly preferred (4).

Stainless steel alloys are highly resistant to corrosion (5). They are more rigid, exhibit less friction, and can be welded. Compared with other alloys, these wires impose relatively higher loads if used at the initial stage of treatment. This leads to the application of high and non-physiological forces during initial treatment even with small cross-sectioned wires. This situation necessitates making bends on wires, thus resulting in disadvantages such as increased chair time and decreased patient comfort.

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Stainless steel alloys also have multi-stranded versions. Having multi-stranded SS is similar with having SS with loops (6). With the same diameter, multi-stranded SS wires have less rigidity. This makes them feasible to use even at the initial stages of treatment; their rigid structure is an advantage during the space closure and finishing phases of the treatment because it prevents unwanted root movements. Overall, SS wires offer clinicians a greater control pertaining to the maintenance of the arch form (5).

Chromium–cobalt (Cr–Co) alloy was first used in a watch company. Approximately 20 years later, it was introduced in orthodontic practice. Cr–Co showed mechanical properties similar to SS. However, it required heat treatment to fully function. The Rocky Mountain Orthodontics Company patented this alloy as *Elgiloy* (7).

A few years later, beta titanium alloy, which was made using titanium, emerged. This alloy underwent changes when subjected to heat treatment. Its atoms underwent structural changes pertaining to their arrangements (8). This alloy is also known as beta-phase titanium alloy. After stabilizing the beta phase of titanium at room temperature in 1977, in 1979, this alloy was introduced in orthodontic practice; it is usually referred to as titanium–molybdenum alloy (TMA) (9).

Beta titanium alloy is rigid and imposes a big amount of force, in other words high loads of force on teeth. However, the wires made of it are easily formed, i.e., they are a good choice for space closure with small bends/loops (9).

William Buehler, a researcher in the Naval Laboratory, U.S., was the one who developed the nickel–titanium alloy (10). He was the first one to observe the "*shape memory effect*" of this alloy. Shape memory is defined as the property of an alloy pertaining to remembering its original shape and after deformation returning to its pre-deformed shape on heat treatment. In 1972, the Unitek Corporation produced the nickel–titanium alloy under the trade name *Nitinol*. By that time, the alloy did not have the shape memory for super elasticity feature. In 1985, a new nickel–titanium alloy was developed with super-elastic features. It was called the Chinese nickel–titanium alloy. This material showed a higher elasticity recovery and lesser stiffness compared to the previous alloy. It also showed lesser permanent deformation after deflection. Similarly, in 1986, another company produced wires made of this alloy under the trade name *Sentalloy*; the alloy this time was referred to as "*Japanese nickel–titanium*" (11,12).

In the 1990s, the nickel–titanium alloy had another version added to its varieties: the thermodynamic nickel–titanium alloy. The wires made of this variety had the same elasticity recovery and resilience features as those of the super-elastic wires; however, they had to be activated by changing the oral temperature (9).

Nickel–titanium alloys are not rigid like SS or beta titanium. Nickel–titanium wires are so elastic that it is difficult to make loops on them, and even after huge deflections, they return to their original shape when the force is removed and the wires are unhanded. As previously mentioned, this property is known as shape memory. Thermodynamic nickel-titanium alloys have an extra advantage of being activated under certain temperatures. Under the activation temperatures, during the application time, it is very easy to fully engage wires made of these alloys into the bracket sloth. Thermally-activated copper nickel titanium's different activation values offer different advantages. For example, the ones that are activated at 27 degrees impose higher magnitudes of loads because they are highly active in the oral cavity, the temperature of which is approximately 36–37 degrees. On the other hand, the ones that are activated at 40 degrees are a great choice for highly sensitive patients because they barely get activated after warm mouth rinses (9).

Copper-nickel–titanium (CuNiTi) alloys are another version of nickel–titanium alloys. They first became available in the mid 1990s. By adding copper to the former nickel–titanium alloy, thermal activation could be more easily controlled. They are marketed based on a variety of transition temperatures: 27 degrees, 35 degrees, and 40 degrees (14).

Finally, because of the increasing aesthetic demand of the patients, the wire companies focused on the development of non-metallic wire materials. In mid 2000s, some companies produced SS wires coated with Teflon or epoxy resin. Some esthetic wires were made of silicon fibers and some were made of polymer composite materials reinforced with glass fibers. These non-metallic wires are esthetically more pleasing, making the treatment more tolerable for patients. On the other hand, this effect is usually temporary because the coating usually peels easily (13).

Having all the general information is useless if an orthodontist does not know how to use these features in clinical practice. The main focus of orthodontists is a fast and painless treatment period with non-pathologic effects on tissues. There are many studies comparing different outcomes of various wires and their working sequences.

Some studies compared archwires with each other and some studies compared archwire sequences instead of comparing initial archwires (14-22). Based on the studies on archwire sequences, when there is a significant difference between two sequences, it is more difficult to determine which wire or wires of that particular sequence was or were more effective and led to a significant difference. However, these studies reveal a lot about the effects of wire sequences.

Pandis et al. (14) compared the alignment performance with respect to the alleviation of tooth irregularity and alignment duration of heat-activated and conventional nickel–titanium alloy in their study. The *in vivo* study design comprised 60 patients. It was a single-center, single-operator, and double-blind randomized trial. All patients had the same amount of mandibular anterior crowding, and they were bonded with the same bracket system. Patients were divided into two groups, one of which was a group of 0.016 in CuNiTi 35 degrees and the other was a group of 0.016 in conventional nickel-titanium. All patients were followed for at least 6 months. It was concluded that there was no significant difference in the alignment duration.

Similarly Kayser et al. (15) and Sandhu et al. (16) who compared the heat-activated (Mact) nickel–titanium with super-elastic (Aact) nickel–titanium stated that no differences owing to the material of the wires was observed on tooth alignment at the initial stage of treatment.

When super-elastic nickel–titanium wires were compared with conventional nickel–titanium wires in terms of aligning effectiveness, there was no significant difference between these wire types (17).

Not only nickel–titanium wire's features were compared with each other. As mentioned before, multi-stranded SS wires can also be the choice for the alignment phase. Researches have shown that their use is as successful as that of nickel–titanium at the time of initial alignment (13,18).

When super-elastic nickel–titanium wires were compared with multi-stranded SS wires in aligning efficiency, different studies showed different results. Although one study found no difference between two groups (19), another study concluded that super-elastic nickel–titanium wire was more effective as the initial wire choice. The difference among results may be due to sample inadequacy and existing bias which may reduce the validity of the results (20).

When multi-stranded SS wires and super-elastic nickel–titanium wires were compared with each other, multi stranded archwires were reported to be significantly more efficient than the other group in terms of the three-dimensional contact point movement (20).

In another study, Mandall et al. (21) performed a clinical research with three wire sequence modules, which were randomly applied to patients. Group A had a sequence of conventional 0.016-inch nickel–titanium, conventional 0.018×0.025-inch nickel–titanium, and 0.019×0.025-inch SS wires. Group B had a sequence of conventional 0.016-inch nickel–titanium, followed by 0.016-inch steels, and finally 0.020-inch SS wires. Last group of the study group C had a sequence of 0.016×0.022-inch CuNiTi wire, followed by 0.019×0.025-inch CuNiTi, and ending with 0.019×0.025-inch SS wire. They concluded that all sequences were equally effective. However, they mentioned that the copper nickel–titanium sequence may be chosen to use by the clinicians to reduce the number of visits until working archwire since copper nickel titanium group is equally effective with less changes of wires. Overall, they agreed with the results of Tidy (22) that the 0.016-inch, 0.018×0.025-inch archwire sequence is an efficient one. They added that in the third archwire sequence (group C), severe rotations could not be solved due to the inability to tie adequately and advised to use another aligning archwire sequence in such cases.

Studies about the Effect of Wires on Pain Levels

Patients endure different levels of discomfort during orthodontic therapy steps. Jones and Chan (23) suggested that the pain induced from archwire placement is much more when compared with that induced by dental extraction.

Erdinç and Dinçer (24) compared the intensity of pain and discomfort resulting from 0.014- and 0.016-inch nickel–titanium wire applications. The results suggested that the thicker 0.016-inch wires were more comfortable, and the analgesic used with them was less. This result is logical when the correlation between analgesic use and pain association is taken into account. A possible explanation for increased amount of analgesic use in the 0.014-inch group may be the anxiety pertaining to probable pain. The pain response was highly and consistently subjective and not related to the dental arch, crowding, sex, or social class; this may be a reason for the unexpected results that were achieved.

Dimensions of archwires can be both advantageous and disadvantageous at the same time. In those with small dimensions, the contact point and friction is less; this has a positive effect on tooth movement and results in a decrease in pain. On the other hand, when the clearance between the wire and bracket sloth increases, the tooth movement control decreases. The same situation allows the clinician to include teeth to the treatment earlier even when they are in crowded and difficult-to-reach positions. Adding these teeth into the treatment during those phases results in movement of more teeth that may increase the pain (25-27).

In a randomized controlled trial, pain perception following first orthodontic archwire placement was compared between heat-activated (Mact) and super-elastic (Aact) nickel–titanium aligning archwires. This trial concluded that heat-activated (Mact) nickel–titanium usage caused less pain. This result can be turned into an advantage during clinical practices comprising highly sensitive patients (12,13,28).

Another study comparing the pain intensity was conducted between super-elastic nickel–titanium and multi-stranded SS wires. The pain intensity was found to be the same between multi-stranded SS and nickel–titanium archwire applications (23).

Several researchers stated that the discomfort peaked at 24 hours after archwire placement and then gradually declined, reaching baseline by day 7 (29).

The application of lesser force means optimized tooth movement and by eliminating unnecessary extra forces consequently lesser discomfort for the patient (21,23). However, Fernandes et al. (30) argued that Nitinol, a super-elastic light force delivering archwire, induces higher pain levels than *Sentalloy*.

In summary, pain recognition has a complex background related to sex, age, force application, ligation technique, soft tissue acceptance, etc. Therefore, the relation of archwire materials and dimensions with pain is still unclear and need further research.

CONCLUSIONS

Having a proper knowledge about wire features is mandatory to be a good orthodontist. Thus, doctors can differentiate among wires and use a sufficient wire sequence suitable for each patient. This can increase the quality of treatment. According to the literature reviewed, there are still some points that have not been clarified in the existing studies. There is a necessity to conduct further and broader studies on initial archwire preferences and the sequence that should be used.

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