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Didactic Material for Arch Wire Characteristics and Properties.

Orthodontic Arch Wires.

Orthodontic arch wires are the main source of tooth moving force in a modern orthodontic system. They work in close concert with orthodontic brackets and their ligating systems. The discussion of arch wires can be quite complex issue because different alloys, shapes and sizes affect the wire's stiffness and resultant force when the wire is deflected (tied in or activated). As with bracket systems, the rationale behind the use of different arch wires by different practitioners varies according to the techniques and philosophy of treatment of each clinician. In an ideal situation, one would only need one (1) biologically efficient arch wire throughout treatment. It would not hurt, break or need any adjustment. Unfortunately, this is far from current reality. Since there are no contemporary arch wires with all the above properties, we must control the force delivered by arch wires by varying the alloy types, wire sizes and cross sections to meet the clinical needs of each individual patient. The choice of an arch wire is primarily driven, first, by its' stiffness and secondly, by its' fit in the bracket slot.

Common Arch Wire Alloys

Stainless Steel

Stainless steel (SS) has been the most popular wire for over fifty years. A typical stainless alloy includes about 71% iron, 18% chromium, 8% nickel, and less than 0.2% carbon. Although stainless has a high content of iron, it does not corrode (rust) in the mouth because it forms a thin protective oxide layer on its surface. Practitioners can easily modify the shape of a stainless steel wire with pliers as it is quite ***formable***. It also has high stiffness, high strength, and a low ***coefficient of friction.*** These characteristics make stainless a good material for opening bites, space closing arch wires and for final finishing wires. For sake of comparison, remember that stainless has a comparative stiffness rating of 1.00.

Chromium Cobalt

Chrome cobalt (CrCo) is a specialty wire often used in lieu of stainless steel. Its' typical composition is about 40% cobalt, 20% chromium, 15% nickel, 15% iron, 7% molybdenum, and 2% manganese. Originally, t was developed by the Elgin Watch Company to be used as a watch main spring *(Elgiloy)*. CrCo is useful because it comes from the manufacturer with a low ***yield point***. This makes it very easy to bend. Once the bending has been completed, it can be heat treated (in the office). Heat treating raises the yield point making the CrCo wire behaves very similarly to untreated stainless steel. This wire is used mostly for wires with multiple loops or bends. It also is used for lab work as very large wires can be bent more easily by the lab tech. It, like stainless, is stiff, strong and has a low coefficient of friction. Chrome Cobalt is slightly stiffer than stainless with a stiffness rating of 1.05.

Nickel Titanium:

These wires have very low stiffness ratings. The typical composition of nickel titanium wire consists of almost 50% nickel and 50% titanium. Nickel titanium (NiTi) wires have a very long range of action. This property is most useful during the first stages of treatment. Conversely, nickel titanium wires are neither very formable nor very smooth. Although they can be deflected large distances, they often break before they take a permanent bend. Don't try to adjust them!

The original nickel titanium wire alloy was borrowed from the Navy Space program. Its first trade name was Nitinol, or Ni*ckel* **Ti***tanium* **N***aval* **O***rdinance* **L***aboratory*, where it was used to expand very compacted antennas from satellites after launching into space. It had the unusual characteristic of heat sensitive ***shape memory*** with which a cool wire could be severely deflected and yet returns to its original shape upon re-heating. Since the temperature of the mouth varies little, this memory phenomenon is of little importance in Orthodontics. NiTi's low stiffness, however, has been a tremendous boon to modern orthodontics

These wires may also be manufactured to include super-elastic properties. Normally, as any wire is bent, its resistance to bending increases in direct proportion to how far it is bent. Super-elastic wires act the same bending forces, as do most wires, up to a point. If they are bent severely, the molecular structure starts to change into a different phase without continuing to build up even more resistance to the continued bending. Super-elastic wires can be bent to the extreme without resisting their deflection nearly as much as normal alloys. When these severely bent wires are tied into a bracket, they slowly lose their force, as the tooth moves. The force is not constant but decays more slowly than normal. Problem: only very small wires can be bent into their super-elastic state without delivering forces that are too high for normal tooth movement.

Despite these unusual characteristics, NiTi wires are very useful because of their very low stiffness. They enable the orthodontist to "fill the slot" with a much softer wire than other wire alloys would allow. The stiffness rating for NiTi wires range from 0.06 to 0.28 making it the least stiff of all alloys.

Beta Titanium

Beta titanium (βTi) wires are now available from multiple manufacturers. Formerly, they were only available from ORMCO under the brand name, TMA (Titanium Molybdenum Alloy). Beta titanium wire stiffness is between stainless steel and the nickel titanium wires. It retains the formability of stainless but is only 40% as stiff as stainless. A typical composition of the beta titanium wire includes 79% titanium, 11% molybdenum, 6% zirconium, and 4% tin. These wires have good strength and good formability but their sliding friction is the highest of all alloys. Since TMA wires have deliver less than half the force levels for the same deflection, as compared with stainless steel, they can be used in clinical situations where force levels lower than stainless steel and higher than nickel titanium are necessary. Beta Titanium stiffness rating is about 0.40.

Gold Alloy: The original arch wires, and bands, were composed of precious metal alloys. These wires were one half the stiffness of stainless and were quite formable with good friction properties. Stainless steel became more popular in the 1950s because of its much lower cost. Gold alloys are no longer used in modern practice. The stiffness rating of gold alloys is 0.50

Arch Wire Selection

The introduction of newer wires to the profession has allowed significant clinical changes in orthodontic arch wire selection and progression. Wires are always chosen to deliver an optimum force. Unfortunately, every wire delivers less and less force as the teeth move. Some newer wires can be left in the mouth for longer periods of time as their force decays more slowly with tooth movement. These less stiff wires deliver more continuous forces over a longer distance of tooth movement.

During the intermediate stages of treatment, the use of larger cross-section NiTi or βTi wires enable difficult movements to be accomplished earlier and faster than was possible with the stiffer stainless steel wires.

To take advantage of the highly variable properties of currently available wires, a rational ***stiffness driven approach*** should be employed based on each particular case. The following is a list of typical wires used at different stages of treatment:

Initial Leveling Stage

Initial arch wires require very high flexibility to adapt to very displaced brackets and tubes. This flexibility can only be obtained with a wire with low stiffness and a very high range. During the initial phase of orthodontic treatment, we are primarily interested in correcting rotations, tipping and vertical discrepancies. An arch wire that allows complete bracket slot engagement with every tooth while delivering low force levels is most desirable. Arch wire options include multi-strand NiTi, small diameter nickel titanium, multi-strand stainless steel, small diameter stainless steel or multi-looped stainless steel wires. The bulk of these wires are much too soft to open the bite or establish good arch form.

Intermediate Leveling

Further leveling and increased arch form control need stiffer arch wires. Larger NiTi or Beta Titanium wires are often used. Stainless steel is better if even more force is needed to open the bite or refine arch form.

Sliding Space Closure

Sliding space closure requires good torque control of the anterior teeth and good arch form control while minimizing wire friction as the space closes. Stainless steel is preferred because of its high stiffness and low coefficient of friction. Do not use the rougher βTi.

Looped Arch Space Closure

Closing loops using lower stiffness wires can be more efficient while still delivering good force levels. Good arch form control and torque control are also important considerations. Beta Titanium can be activated more while stainless wires can exert more control over torque and arch form.

Intermediate Torque Correction

Large dimension square ,nickel titanium or beta titanium wires are usually the wire of choice for beginning torque control of tooth movement. These softer alloys permit lower initial torquing forces than are possible with steel wires of the same size. Steel is often later used to finish up torque correction.

Finishing Stages

A finishing wire needs to be capable of final torque and arch form adjustments while most of all, be formable and of medium stiffness. The lower the stiffness, the larger any finishing adjustment can be. Stainless steel or beta titanium alloys are most often used in the finishing stages. These wires provide stability and formability for fine tooth movements and detailing.

However, flexibility is of essence during the final finishing phase to allow settling of the occlusion following space closure and idealization of tooth positions during the intermediate and early finishing stages. Sectioning the stainless steel or titanium molybdenum alloys, using light wires or multi-strand stainless steel wires are also appropriate options during this phase. Often, no wires at all, are used with vertical elastics in the posterior quadrants during final settling.

Arch Wire Shapes

Originally, all gold and stainless arch wires were custom formed by the orthodontist from straight wire stock. Over time, more and more preformed arch wires have become available to the point that every wire alloy comes in multiple wire dimensions and various pre-formed arch shapes. Nickel titanium arch forms are set during manufacturing. Since NiTi is not very formable, you have little control over its pre-determined shape. Beta titanium, stainless and chrome cobalt wires, however, are quite formable so the factory delivered arch forms can be easily modified at any time.

Arch Wire Sizes and Dimensions

All arch wire sizes are described in thousandths of an inch. Sometimes arch wires may also be described in mils., i.e. 1 mil = .001 inches. Wires are never larger than their nominal size but they are usually slightly smaller than their nominal size. A round arch wire is described by its diameter in thousandths of an inch. For example, .016 ss wire represents a round 0.016 thousandth of an inch stainless steel wire. For rectangular wires, both dimensions are listed. The first number is the vertical thickness while the second number is the horizontal thickness of the wire. For example, .016 x .016 ss represents a square stainless steel square wire that is .016 thousandths of an inch thick and .016 thousands of an inch wide. A .017 x .025 ss wire represents a rectangular stainless steel wire that is .017 thousandths thick and .022 thousandths wide. A rectangular arch can be thicker than it is wide (ribbon arch). Example: .022 x .016 is a ribbon arch that is .022 in. thick and only .016 in. wide.

Ligature systems

Ligation is the process of securing the wire to / within an orthodontic bracket. There are several methods of achieving this ligation. The following are the most common methods:

Elastic Modules

Elastic modules are small "O rings" made of biocompatible plastic. They are normally placed under the four wings of the bracket and go over the arch wire near the mesial and distal of the bracket. They normally hold the arch wire firmly against the base of the bracket slot. If the tooth is rotated and the arch wire is too stiff, the elastic ligature will stretch more and not hold the arch wire firmly against the bracket slot base. Elastic modules can stretch more than wire ties and are therefore less likely to de-bond brackets. The elastic rings can be placed more quickly than stainless steel ligatures. Many of the younger patients are enthusiastic about the various available colors.

Unfortunately, the elastic modules create much more sliding friction and attract more plaque than their steel counterparts. They also deteriorate fairly quickly in the mouth losing their effective force in a relatively short period of time resulting in forces that are too low to be effective. Because of these decay properties, elastics must be changed more frequently than steel ligature ties that can remain in place almost indefinitely.

Stainless Steel Ligatures

Steel ligature ties are thin fully annealed (dead soft) wires which makes them very flexible and formable. The ligature wire is threaded under two tie wings, over the arch wire distal to the bracket, under the other two wings while finally crossing over the arch wire, again, mesial to the bracket wings. The two free ends of the ligature wire are twisted together tightly and then cut leaving a "pig tail" of 2-3 mm. The remaining "pig tail" is tucked out of the way under the arch wire. Because the ligatures do not stretch, the steel ligatures' seating force does not diminish over time. This also permits using more force to seat the arch wire than is possible with elastic ligatures. Full engagement of a wire with a long range of action results in a more continuous force application. Steel ligatures sliding friction can be reduced to the levels of a self-ligating bracket.

Self-ligating Bracket

Self ligating brackets do not use either ligatures or elastic modules to hold the arch wire within the bracket slot. Instead, they have a moveable fourth wall on the buccal surface of the bracket. When the wall is "open", wires can be either placed or removed by sliding the arch wire through the buccal opening. After a new arch wire is placed in the slot, the moveable wall is moved into place converting the open bracket slot into a closed tube. Closing the fourth wall usually deflects the arch wire creating orthodontic forces. Some self-ligating brackets have a spring mechanism that hold the arch wire closer to the slot floor that the fixed fourth wall tube systems do.

Several brands and types of ligature-less, self-ligating, low friction brackets have become available in recent years (e.g. Damon [Ormco], Innovation R [GAC Int.]. The popularity of these brackets seems to be increasing. Such brackets offer advantages of saving time, reducing some friction, and increasing patient comfort and oral hygiene levels.