WHITE PAPER SERIES

Introduction to the technological and clinical benefits of SmartArch

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Abstract

Smarter Alloys' new orthodontic product, SmartArch, is a revolutionary new archwire that is programmed to express the biomechanically optimized force at each individual tooth. Using a laser treatment process, the wire stiffness in each interbracket region is encoded to deliver the required forces. This improvement in stiffness resolution and control offers significant improvement and benefits over traditional multiforce archwires currently in the market, which are limited to 3 stiffness regions that gradually increase distally from the centerline. The SmartArch Universal stiffness profile is based on the biologically correct tooth moving forces for the periodontal ligature root support and interbracket spacing of the individual teeth. This targeted force control allows each tooth to be engaged concurrently and enables efficient movement while limiting unwanted anchorage loss. SmartArch is compatible with a typical workflow and works with most bracket systems without the need for special tools or equipment.

Introduction

SmartArch is a revolutionary technology that delivers pinpoint control over the forces applied to specific teeth. This development dramatically improves the performance of traditional multiforce archwires which are limited to three stiffness regions. The optimized individual tooth forces expressed by SmartArch wire offers significant clinical advantages and makes a compelling case for adding SmartArch to your working wire toolbox.

Background: multiforce archwire

The number of multiforce archwires on the market has proliferated over the last few years to the point that nearly every major orthodontic distributor now offers these appliances under one name or another. These multiforce archwires are nearly identical in design, featuring three stiffness regions. This stiffness profile is a design limitation common to every multiforce archwire and is a result of the selective heat treating manufacturing process, which is similar to all.

Multiforce archwires are typically divided into three regions: the posterior region, where the superelastic stiffness is highest; the bicuspid region, where the superelastic stiffness gradually decreases in the mesial direction; and anterior region, where the stiffness is lowest. This stiffness profile is suggested by the manufacturers to be biologically ideal because larger posterior teeth require higher forces than smaller anterior teeth.

There are several problems with this. First, local archwire stiffness does not correlate directly with the force expressed at the bracket when the interbracket distance changes along the arch (Figure 1a). Larger interbracket spacing results in lower wire bending moment for a given activation, and vice versa. Second, the ideal biological force for a tooth is a function of the periodontal ligament root support and does not simply increase distally at the same rate of stiffness change delivered by multiforce archwires. It is a gross oversimplification to say that a multiforce archwire with a gradually decreasing stiffness profile will express a similar force profile, or that the force profile will be biologically correct.

How is SmartArch different?

SmartArch wires are programmed with different and distinct stiffness in each interbracket region (Figure 2). This enables each tooth to be targeted with the optimal force. The SmartArch stiffness profile is optimized for both periodontal ligament root support and interbracket distance. The result is an archwire with much greater control over individual forces at the bracket compared with traditional archwires.

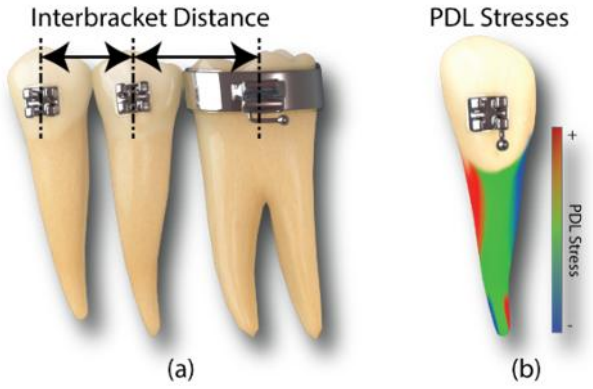

Figure 1: (a) The interbracket distance between teeth affects the force delivered to the bracket by the archwire as a result of the bending moment in the wire (b) The periodontal ligament (PDL) stresses are induced by force applied at the bracket and are a function of the PDL length.

Programmable archwire

At the heart of SmartArch technology is the Smarter Alloys'™ process for programming the stiffness of superelastic wires. Each segment of the archwire is laser treated to encode the material microstructure for varying heat activation temperatures. This proprietary technology enables complex stiffness profiles along the length of the wire. The result is an archwire which can express a range of continuous superelastic forces for similar activations. With SmartArch, the wire stiffness can be programmed with sub-millimeter resolution, enabling each tooth to be targeted with biomechanically optimized force.

Ideal physiological forces

Tooth movement is the biological response to stresses in the cementum, periodontal ligament and bone resulting from forces applied by the archwire. At low stress levels, bone resorption is slow to occur and tooth movement is slow. At high stress levels, undesirable tissue changes (aseptic necrosis and hyalinization) result in delayed tooth movement. At optimum stress levels, the maximum tooth movement rate and remodelling occurs. As stress is a function of the periodontal ligament root support (Figure 1b), optimal tooth movement requires that the force expressed by the archwire be targeted.

Figure 2: SmartArch Engineered Archwire is programmed with a biomechanically optimized stiffness profile. Each interbracket region has an ideal stiffness, shown here by a different wireframe color overlay, to deliver the biologically correct forces to the targeted tooth.

The optimized biomechanics for tooth movement and retention were determined by modelling the dentoalveolar complex. Drs. Charles Burstone and Rodrigo Viecilli implemented the finite element method to simulate the dentition of a typical typodont. The results were used to develop archwire stiffness profiles that, when interbracket spacing is considered, are able to deliver ideal individual targeted forces (Figure 3).

The SmartArch Universal profile

The SmartArch Univeral stiffness profile has been biomechanically engineered to express the ideal forces for each tooth based on typical interbracket spacing along the arch. The forces expressed by the wires have been modelled using finite element analysis and verified using a 3-bracket bend test (Figure 4). This test setup more accurately reflects the actual forces being experienced at the bracket because it accounts for the bracket slot width and frictional effects and allows for interbracket spacing adjustments. Table 1 shows the FEA modeling results and comparison between SmartArch Universal and a typical multiforce archwire.

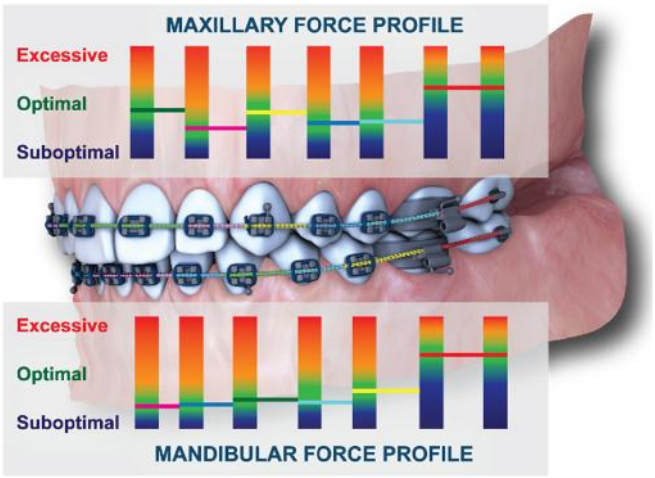

Figure 3: The ideal physiological forces as derived from the PDL root support for each tooth. The target tooth moving force is shown for each tooth by the coloured line and corresponds to the 3-bracket bend test force measured in each interbracket region with a matching color overlay.

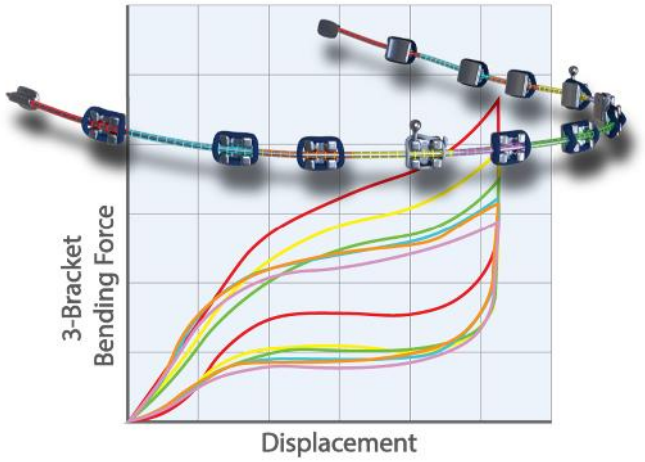

Figure 4: Representative 3-bracket bending test results for the SmartArch Universal maxillary profile. The ligating (loading) force and unloading forces are shown. Note the difference between the constant continuous forces for each curve.

SmartArch wires are based on the superelastic Copper Ni-Ti alloy system for low hysteresis and exhibit the same constant and continuous forces upon unloading over large activations that make superelastic wires so attractive. The wire is a 0.016" (0.406 mm) round wire programmed to deliver between 80 gf and 200 gf. It is important to remember that with SmartArch, wire stiffness is not a function of the wire size, but is programmed locally into each interbracket region. Due to differences between maxillary and mandibular dentition, the profile has been optimized for both upper and lower archwires, respectively. SmartArch is currently available in an archform comparable to Damon®[1], with other archforms and cross-sections under active development.

The individual stiffness properties in each interbracket region are obtained by varying the heat activated temperature of the segment. Lighter force segments have higher heat activation temperatures and may appear relaxed at room temperatures. This feature makes it easier to ligate smaller teeth that are more sensitive to forces.

The SmartArch Universal stiffness profile features distinct segments with a constant stiffness in each interbracket region. This profile is designed so that the segment extends from the mesial edge of the target tooth bracket distally to edge of the next bracket. This design allows for wire to be consumed as it is ligated in the malocclusion without dramatically changing the forces applied to neighbouring teeth.

Clinical benefits of SmartArch

SmartArch wires feature the constant force-displacement property of superelastic archwires while adding precision control over wire stiffness in each interbracket region. Because the ideal force is applied to each tooth, SmartArch wires will allow concurrent tooth movement while preventing unwanted anchorage movement. Several archwire progressions can be eliminated because the SmartArch wire spans the full range of superelastic wire stiffness that are needed for effective treatment.

Fits within your current workflow

SmartArch wires have the same physical appearance as a standard NiTi archwire (Figure 5). SmartArch wires work with conventional and self-ligating bracket and hook systems commonly used. SmartArch wires are chairside and ready to be installed without any impressions, scans, fixtures, or off-site

Table 1: Comparison of FEA bracket unloading force results for 1.5 mm activation with the ideal physiological force model results for a regular 0.014 in Copper NiTi archwire; a 0.016 in multiforce archwire; and the SmartArch Universal archwire (0.016 in).

		0.014" CuNiTi Force (N)	**0.016" Multi-force Force (N)**	**SmartArch Universal Force (N)**	***Ideal Physiological Force (N)***
Mandibular	L1	1.38	0.41	0.82	***0.80***
	L2	1.32	0.39	0.81	***0.80***
	L3	1.15	0.42	1.09	***1.04***
	L4	1.29	0.60	1.04	***0.99***
	L5	1.05	0.80	1.18	***1.18***
	L6	1.05	0.84	1.82	***1.90***
Maxillary	U1	0.80	0.24	1.22	***1.34***
	U2	0.80	0.25	0.90	***0.88***
	U3	0.89	0.38	1.29	***1.24***
	U4	0.66	0.65	1.24	***1.22***
	U5	1.29	0.80	1.25	***1.21***
	U6	1.08	0.91	1.66	***2.20***

[1] Damon is a registered trademark of Ormco Corporation. Smarter Alloys implies no endorsement by Dr. Dwight Damon

wire bending. No special systems, equipment, or training is required.

One SmartArch wire replaces all round superelastic archwire progressions typically used for 1st and 2nd order corrections. SmartArch is recommended for any case in which a light superelastic wire would be inserted to begin treatment. The SmartArch Universal force profile is designed to work with most mild to moderately severe cases. Best performance is expected when the archwire is engaged no more than 5 mm.

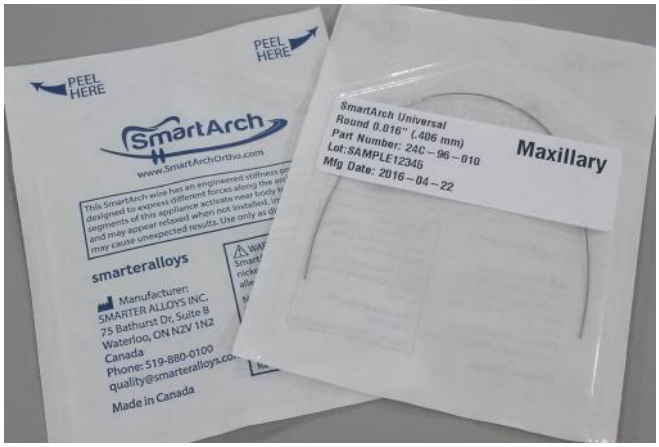

Figure 5: SmartArch wires come in a standard medical grade sterilisable pouch and are available in a 10-pack.

Recommended use

1. Start by inserting the wire in the bracket slot of the tooth that is displaced furthest from the ideal archform, progressively inserting teeth following the same criterion.
2. Keep the midline of the archwire coincident with the treatment midline you have chosen and make corrections by sliding the archwire mesio-distally as you insert the archwire in the slots. This ensures the SmartArch force profile remains aligned to each tooth.
3. Use a ligature director to push the wire into the slot. An icing spray on the tip of the instrument to cool it down will help facilitate insertion.
4. Always fully activate the archwire before inserting into the slot to ensure optimal unloading force.

What to expect

In clinical case studies, SmartArch Universal demonstrated highly efficient malocclusion resolution, with concurrent rotation and arch development while unwanted movement was limited. In these cases, such as shown in Figure 6, the SmartArch Universal working wire was placed at the beginning of treatment and left in place for several months.

Figure 6: Concurrent incisor alignment and premolar rotations with a single SmartArch Universal archwire.

Smart innovation

SmartArch is a quantum leap forward in orthodontic technology that will revolutionize the way you think about archwires in your treatment planning. From the use of the latest in superelastic materials, to the high precision programming process, to the advances in computer simulation and use of instrumented testing, SmartArch is the result of radical innovation in the state-of-the-art. The future of orthodontics is SmartArch.

For more information on SmartArch, visit: www.smartarchortho.com

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