Archwire Sequence for Insignia®: a Custom Bracket System with a Bright Future

Abstract

Insignia® system is a reverse-engineered production of customized brackets, based on the desired final alignment: "begin with the end in sight." Efficient sequencing is the key to efficient management of a malocclusion with progressive archwire therapy. Each step in active treatment is directed toward a specific objective, consistent with ensuring patient comfort, maximizing the potential of each step in treatment, and achieving alignment to place the final archwire as soon as possible. There are four phases in Insignia® progressive archwire therapy: (I) stock light round wires, (II) customized rectangular copper-nickel-titanium (CuNiTi) wires, (III) major mechanics as needed, and (IV) finishing. This article recommends archwire sequencing, based on clinical experience with the Insignia® bracket system. In addition to traditional progressive archwire therapy, the Insignia® system is well designed for segmental determinate mechanics, to decrease PDL compressive stress. Segmental mechanics, with extra-alveolar bone screw anchorage and anterior bite turbos, is designed to enhance outcomes and decrease treatment time by increasing the rate of tooth movement and controlling root resorption. (Int J Orthod Implantol 2017;46:60-69)

Key words:

Insignia® system, passive self-ligating bracket, archwire sequence, custom bracket, custom torque, low PDL stress, enhanced rate of tooth movement, decreased root resorption

Introduction

Insignia® (*Ormco, Glendora, CA*), introduced by Dr. Craig Andreiko in 1987 (*Fig. 1*), involves two components: (*1*) customized brackets, placement gauges, and archwires, and (2) three-dimensional (*3D*) real-time virtual treatment planning software. A bracket set is precisely designed for ideal alignment of an entire arch on a full dimension rectangular archwire.

The process begins by digitizing the patient's skeletal and dental anatomy: scanning PVS impressions or direct dental scanning (*Fig. 2a*). The teeth are aligned into an ideal position (*Fig. 2b*) with a digital 3D positioning algorithm that assists

Fig. 1:
Dr. Craig Andreiko (1950-2013) was the inventor of the Insignia® bracket design system based on a futuristic 1992 patent.

Dr. Angle Lee,
Director, Bell Dental Clinic, Taiwan
Editor, International Journal of Orthodontics & Implantology (Left)

Dr. Chris Chang,
Founder, Beethoven Orthodontic Center
Publisher, International Journal of Orthodontics & Implantology (Center)

Dr. W. Eugene Roberts,
Editor-in-chief, International Journal of Orthodontics & Implantology (Right)

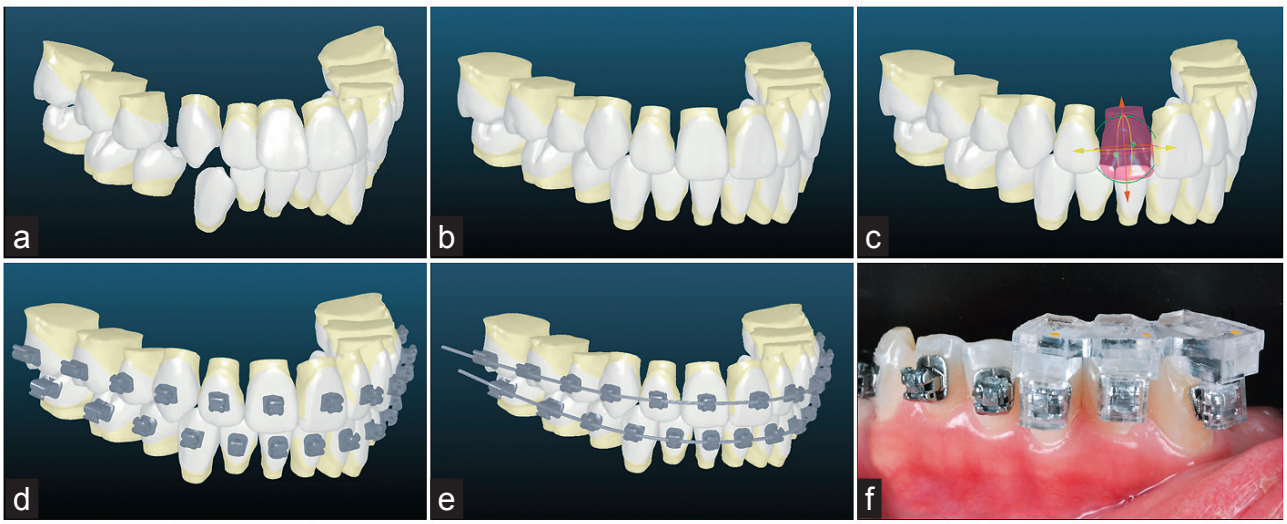

Fig. 2:
(a) Patient's oral anatomy is digitized in 3D.
(b) Based on the practitioner's treatment plan, all the teeth are digitally aligned in 3D to an ideal position via an algorithm for automated intermaxillary alignment.
(c) Any tooth can be adjusted in 3D as specified by the clinician.
(d) According to an ideal tooth position approved by the clinician, the Insignia® system reverse-engineers the production of a custom bracket for each tooth.
(e) Straight archwires are constructed as specified by the ideal set-up.
(f) Bracket-positioning jigs are fabricated to provide accurate bonding of each bracket.

in tooth alignment consistent with the underlying skeletal support (*Fig. 2c*). According to the desired tooth alignment (*Fig. 2b*), the system produces custom brackets (*Fig. 2d*) and archwires (*Fig. 2e*) by a reverse engineering process. Bracket-positioning jigs are fabricated to assist the clinician in accurately bonding a customized bracket on each tooth (*Fig. 2f*). The precise placement of each bracket is critical for producing a 3D alignment (*Fig. 2d*) to accommodate the final rectangular finishing wire (*Fig. 2e*).

The Insignia® system is a reverse-engineered fixed appliance for comprehensive dentofacial orthopedic treatment; this is a major advance for comprehensive treatment of all malocclusions. The clinician prescribes a custom appliance to optimize the treatment of each patient by digital simulation of the final desired result. Automated management, of the demanding technical aspects of routine alignment and leveling, allows the practitioner more time to concentrate on treatment

planning for advanced mechanics to resolve even severe skeletal malocclusions conservatively (*no extractions or orthognathic surgery*).[1] Insignia® was designed to utilize the established preferences of doctors, for creating a custom appliance with a preferred bracket system. Insignia® offers clinical efficiency for controlling and minimizing variables to achieve optimal results with minimal treatment duration.[2-5] Bracket torque, archwire configuration, and bonding positions are designed by the Insignia® system, but the archwire sequence is selected by the clinician. Based on clinical experience, this article recommends an archwire sequence for each stage of Insignia® progressive archwire treatment, utilizing passive self-ligating (*PSL*) brackets. All products described are obtained from Ormco Corporation, Glendora CA, except where specified.

Phase I: Stock light round wires

The objectives for the first phase of treatment are: (*1*) level and align, (*2*) initiate arch development as needed, and (*3*) resolve 90% of the rotations. A stock 0.014-in Damon® copper-nickel-titanium (*CuNiTi*) wire is used as an initial archwire to resolve interdental discrepancies and level the arches. The small dimension of the initial round archwire minimizes friction and binding between the wire and the tube-like lumen of the PSL brackets (*Fig. 3*). With this mechanism the teeth can slide freely along the wire as they are leveled and aligned. To manage severe crowding, narrow arch form and/or compromised periodontal support, a stock 0.016-in or 0.018-in Damon® CuNiTi archwire can be used as an alternative second archwire to further align and level the dentition.

The purpose of these round CuNiTi wires in the Phase I (*initial stage*) of treatment is not to completely resolve rotations, but to provide adequate alignment of brackets to atraumatically transition to the second phase in the sequence (*rectangular archwires*). If a patient feels pain, or the brackets dislodge when closing the slide, progression to the rectangular wire(*s*) is premature.

Phase II: Insignia® Rectangular CuNiTi wires

The objectives of the second phase are: (*1*) start resolving torque and root angulation problems, (*2*) complete leveling and alignment, (*3*) finish

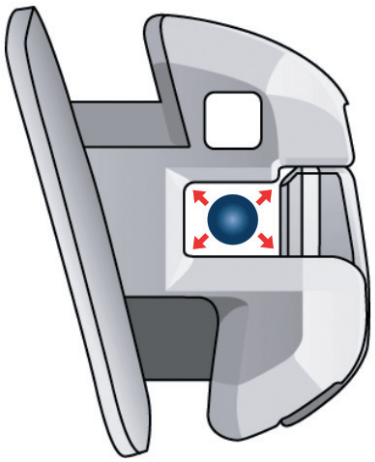

Fig. 3:
Small dimension round wires minimize frictional binding between the tube-like lumen of the PSL bracket and the continuous archwire. This allows the teeth and brackets to slide freely along the wire during leveling and alignment.

Insignia Archwire Sequencing			
I	Stock light round wires	0.014 0.016 / 0.018 (alternative)	Stock Damon CuNiTi
II	Insignia edgewise CuNiTi wires	0.014 x 0.025 0.018 x 0.025 0.021 x 0.025	Insignia CuNiTi
III	Major mechanics	0.019 x 0.025	Stock SS
IV	Finishing	0.021 x 0.025 0.021 x 0.025 0.019 x 0.025 (backup)	Insignia CuNiTi Insignia TMA Insignia TMA

■ Table 1: The recommended archwire sequence is summarized for progressive archwire therapy utilizing the Insignia® bracket system.

rotation corrections, and (*4*) continue arch form development, as needed. The recommended Insignia® CuNiTi rectangular archwire sequence is 0.014x0.025-in, 0.018x0.025-in, and 0.021x0.025-in. Each archwire must be inserted with minimal active engagement, or the arch is not ready to progress. Minor spacing in the anterior segments is consolidated with elastomeric chains. The latter full sized CuNiTi archwire is used to prepare for insertion of the 0.019x0.025-in stainless steel (SS) wire in the next phase.

Phase III: Major mechanics

The objectives of the third phase are to close posterior spaces as well as to correct anteroposterior and intermaxillary relationships. All teeth in the anterior segments of each arch are retracted en masse (*altogether*). Consistent with a straight wire approach, a stock 0.019x0.025-in SS archwire is used for sliding mechanics. A relatively rigid SS archwire (*0.017-in or 0.019x0.025-in*) is recommended for maintaining the integrity of the arch during space closure, either by chains of elastics or closing loops; rigidity across edentulous segment is particularly important for large extraction spaces. The stock SS archwire is adjusted to fit the patient's specific arch form before insertion. Moreover, reduction of the SS archwire in the posterior segments is recommended to control bracket friction and binding when closing spaces with elastomeric chains.

In addition, if intermaxillary correction is required, OrthoBoneScrews® (*OBSs*)(*Newton's A, Hsinchu City, Taiwan*) are an ideal source of anchorage for the Insignia® system. OBSs are typically placed buccal

Fig. 4:
The maxillary occlusal view of the treatment sequence is shown over 13 months using Insignia® progressive archwire therapy. The archwire and months of treatment are shown at the top and bottom of each photo.

to the molars in each arch to provide skeletal anchorage that does not interfere with dental alignment or the path of tooth movement. Each arch can be retracted, intruded or rotated to resolve even severe malocclusions conservatively.[6,10]

Phase IV: Finishing

The objectives of the fourth phase of treatment are to complete torque expression and final detailing to achieve ideal intra-arch and intermaxillary alignment. An Insignia® 0.021x0.025-in CuNiTi wire is placed to achieve the full expression of the digital set-up. If needed, final finishing is achieved with an Insignia® 0.021x0.025-in TMA archwire. It is important to order the final TMA archwire as a backup, because uncontrolled anatomical variables can result in minor alignment discrepancies, that are easily managed with routine finishing adjustments.

Figs. 4 and 5 are sequences of intraoral photographs documenting the treatment with Insignia® progressive archwire therapy.

Discussion

The low force to deflection-rate (*resiliency*) of an 0.014-in CuNiTi archwire results in the application of a relatively low load over an extended range. These are desirable characteristics for a more physiologic approach to orthodontic therapy: applying adequate force to stimulate cellular activity in the periodontal ligament (*PDL*) without occluding its vascularity.[7] The 1932 Schwartz[7] proposed a 2D histologic concept: if PDL compression in the line of force exceeds capillary pressure (*<16kPa*),[1] necrosis (*hyalinization*) of the PDL results. More recent experimental studies have demonstrated the importance of modeling PDL compressive stress in 3D because teeth do not

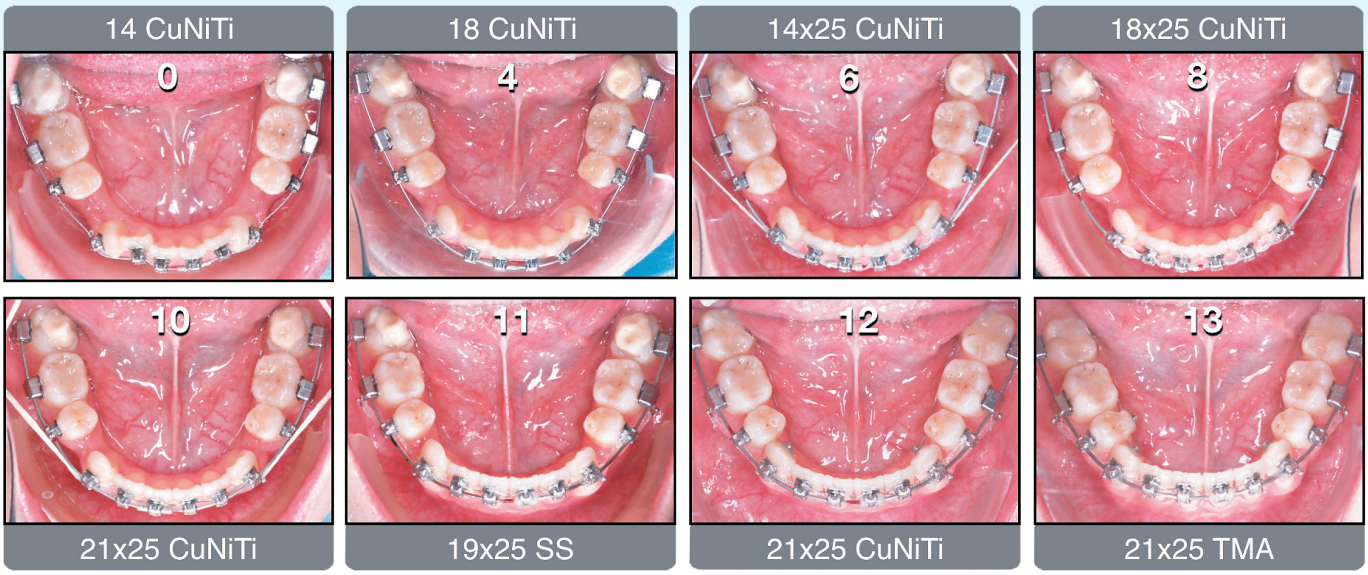

Fig. 5:
The mandibular occlusal view of the treatment sequence is shown over 13 months using Insignia® progressive archwire therapy. The archwire and months of treatment are shown at the top and bottom of each photo.

always move along the plane of the force.[8] Rodent tooth movement studies analyzed in 3D with finite element analysis show that 8-10kPa is associated with PDL necrosis,[9] which is less than the 16kPa required to occlude capillaries.[1]

Recurrent PDL Necrosis: Episodes of PDL hyalinization (*necrosis*) decrease the rate of tooth movement and enhance the expression of external apical root resorption (*EARR*). PDL necrosis at the initiation of tooth movement is well known.[11-13] Furthermore, histologic data suggests that periodic occlusion of the PDL is probably recurrent throughout the entire course of comprehensive treatment, with both fixed and removable appliances. Even the relapse of unretained teeth can result in PDL necrosis.[11,12] Thus, relatively low levels of PDL compressive stress results in necrosis, which is manifest as a lag phase in tooth movement.[11-13] Routine archwire changes and reactivation of appliances results in recurrent loading of teeth which may result in a continuing series of lag phases. Even modest lateral force on the crown of a tooth produces substantial compressive stress in PDL near the apex of the root. This phenomenon in physics is due a long lever-arm between the bracket and the center of rotation (C_{rot}) of the root: ~10mm or more. A relatively light clinical force ($\leq 25cN$) at the bracket level generates a large moment ($\sim 250cN\text{-}mm$) around the C_{rot} which is usually ~0.40% down the length of the root.[13] The movement of the apex in the opposite direction of the applied force crushes the PDL in a relatively small area ($1\text{-}3mm^2$), because of the anatomical irregularity of root and bone surfaces.[11-13] The relatively large reactive force applied to a small area of the PDL near the apex results in compressive stress of a MPa or more. The crushed PDL produces a lag phase in tooth movement which may last 2

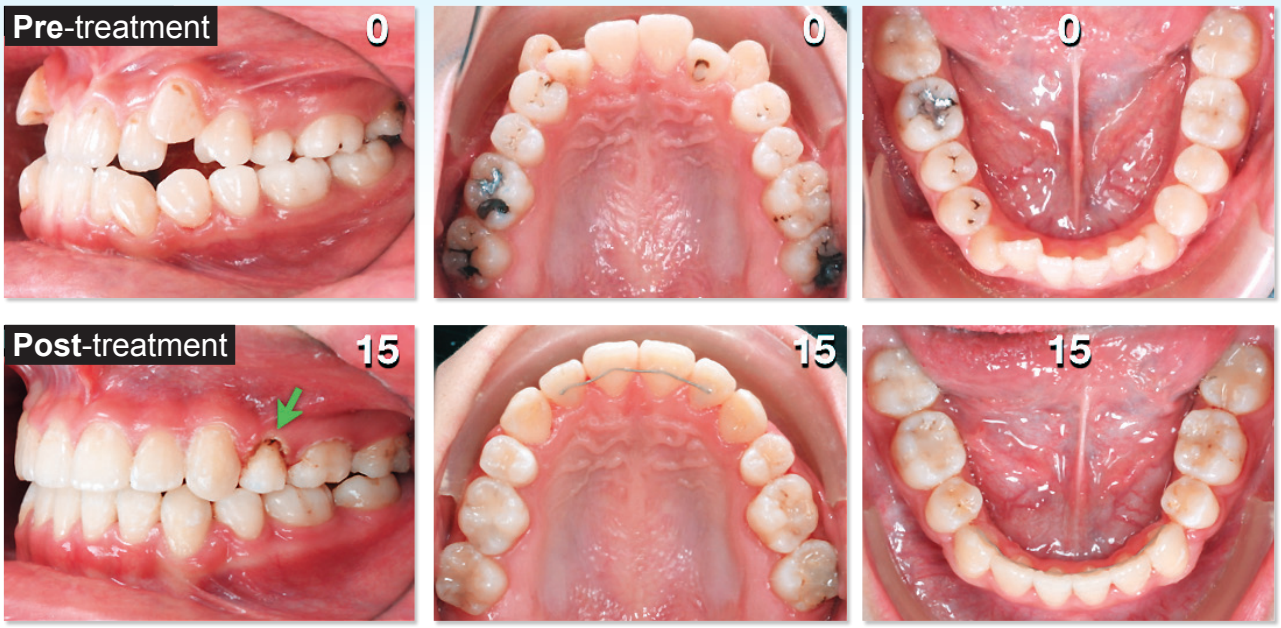

Fig. 6:

*a: **Pre-treatment intraoral photograph:** A Class III malocclusion with anterior crossbite and crowding case is prepared for treatment with Insignia® progressive archwire therapy.*

*b: **Post-treatment intraoral photograph:** After 10 visits in 15 months, the dentition has been treated to a Class I molar relationship with an ideal overbite, overjet, and alignment. Gingival recontouring is accomplished with a diode laser (green arrow). Fix retainers are bonded on all maxillary incisors, and from canine to canine in the mandibular arch.*

weeks or more.[11-13] The usual pattern of engaging individual teeth on multiple archwires and periodic reactivation probably generates a continuing series of PDL necrotic episodes (*lag phases*) that increase treatment time. Thus comprehensive orthodontics with progressive archwire therapy requires an extended period of time (*2-3 years*) because the rate of tooth movement is relatively slow. Controlling PDL compressive stress is a high priority for advanced mechanics to enhance the rate of tooth movement and decrease the incidence of root resorption. The Insignia® system is an ideal, fixed appliance platform for developing a new generation of mechanics to increase the rate of tooth movement and decrease the incidence of root resorption (*Fig. 6*).[1]

Enhancing the Rate of Tooth Movement: Adult second mandibular molars, engaged as single teeth on an archwire, move at a sustained rate of about 0.3mm/mo.[10] However, second molars as part of a mandibular arch, that is engaged as a segment, connected by a rigid archwire, are intruded about 6mm in 6mo.[9] Thus, the maximum rate of molar movement for the entire arch as a segment was ~1mm/mo, which is about three times the rate of sustained molar movement with routine mechanics.[10] This rapid rate of tooth movement appears to reflect decreased PDL necrosis, because the PDL compressive stress for all teeth in the segment was spread uniformly over the surfaces of all the roots in the segment, resulting in stress <5kPa,

which is well below the threshold for PDL necrosis.[8] These data suggest that treatment time and risk of EARR can be decreased if the arches are moved as segments rather than individual teeth, engaged on a series of progressive archwires.

Controlling PDL Stress: Within the limits of current technology, avoiding at least some PDL necrosis is improbable, during routine alignment and leveling with even the lightest, most resilient continuous archwires. When an archwire is activated, the load delivered to a tooth is directly related to the discrepancy between the bracket slot on the tooth and configuration of the unloaded archwire. The most malposed teeth receive the highest direct loads, but all teeth on a continuous archwire are indirectly loaded to some degree, because they anchor the load delivered to the malaligned teeth as the archwire is engaged. The only evidence of long-term tooth movement free of PDL necrosis is segmental movement of the entire mandibular arch to correct Class III openbite malocclusion.[1] For that clinical application, continuous and relatively uniform light force was applied with bilateral 200cN NiTi coil springs, anchored by mandibular buccal shelf OBSs. The continuous mechanics retracted and distally rotated the entire mandibular arch, resulting in about a 6mm intrusion at the apex of the second molars.[1] Finite element analysis of the root surface for all mandibular teeth demonstrated that PDL compressive stress was a relatively uniform at <5kPa, which is well below the threshold for PDL necrosis, which is 8-10kPa in rodents.[9] The concordance of these data from clinical and animal studies suggest that pressure necrosis in the PDL of rodents and humans involves similar levels of compressive stress. To control pressure necrosis, and the associated root resorption, it is necessary to avoid loads that produce compressive stress anywhere in the PDL that is ≥10kPa.[9]

Initial Alignment and Leveling: The precise bracket position and torque of the Insignia® system is an ideal platform for accomplishing initial alignment and leveling in a relatively atraumatic manner. Small dimension, round CuNiTi archwires are effective for correcting rotations and aligning marginal ridges, but may lack the buccal stiffness to level the arch. New materials, manufacturing processes and/or clinical methods are needed to gently accomplish optimal initial alignment, leveling and torque control with a single archwire. A single archwire approach eliminates the repetitive lag phases in tooth movement due to multiple archwires with progressive stiffness. In addition, the efficiency of relatively atraumatic alignment can be improved by three currently available clinical methods: 1. differential enamel stripping of well-aligned teeth to make space to align crowded teeth,[14] 2. retracting canines with OBSs, placed buccal to the molars,[15] and 3. anterior bite turbos constructed on the palatal (*lingual*) surfaces of anterior teeth to open the vertical dimension of occlusion (*VDO*), as needed.[16] The objective for initial alignment and leveling is to atraumatically align each arch to receive a full-size rectangular archwire as soon as possible. A reverse engineered bracket system such as Insignia® is ideal for mechanics that minimize PDL compressive stress.

Segmented Arch Mechanics: Mechanics minimizes PDL stress focus on aligning each arch as a segment, connected with a full-size archwire. Major mechanics are accomplished with intermaxillary elastics and bone screw anchorage buccal to the molars.[5,9,15] In effect, a segment of teeth, connected with a rigid archwire, is equivalent to a large multi-rooted tooth. Segments have distinct advantages with respect to the physics and physiology of orthodontics. When force is applied to the archwire in a rigid segment, the mechanics are determinate, so that all loads (*forces and moments*) in the applied system can be calculated with static equilibrium equations.[17] Thus, the compressive stress in the PDL is known when a determinate load is applied to a tooth or segment. From a physiologic perspective, PDL stress is distributed over the entire root surface of all the teeth in the segment.[1,17] This is a critically important advantage for controlling PDL necrosis under experimental or clinical conditions. When the PDL remains patent under conditions of compressive loading, the osteoclasts can continuously remove bone in the path of tooth movement, thereby increasing the rate of tooth movement while decreasing the incidence of root resorption.[7-9]

Insignia® System Advantages: Determining precise bracket position and torque, by reverse engineering from the desired final alignment, has obvious advantages for progressive archwire therapy, the current mainstream of orthodontic therapy. However, this high-technology precision appliance is also a critical step in the evolution of advanced biomechanics to enhance outcomes and decrease treatment time.[1] The precisely defined brackets facilitate the initial alignment and leveling to receive a rigid straight archwire in each arch, so that the major correction can be accomplished with determinate, low PDL stress mechanics. Extra-alveolar (*E-A*) bone screws are ideal anchorage for moving arches as segments. Precision customized brackets, E-A bone screws and anterior bite turbos are well established(*Fig. 6*).[1,6,15,16] The current challenge is to develop materials and methods for relatively atraumatic initial alignment in preparation for major mechanics, with innovative methods, to resolve the skeletal malocclusion with segmental treatment.

Conclusion

1. Progressive archwire therapy with the Insignia® system "*begins with the end in sight*" and all mechanics are a direct progression toward the desired final alignment along a straight wire. The recommended archwire sequence is summarized in Table 1. Clinicians select archwire sizes and materials according to the treatment plan. It is important to allow each archwire adequate time to provide the prescribed degree of alignment in preparation for the next archwire.

2. Insignia® is a futuristic fixed appliance, compatible with innovative 3D concepts in biomechanics. A low PDL stress approach focuses on: 1. relatively atraumatic alignment and leveling with multi-force archwires, 2. anterior bite turbos to correct the VDO, 3. E-A OBS anchorage, and 4. segmented

determinate mechanics to move entire arches en masse. These methods promise to expand the scope of treatment, enhance outcomes, decrease treatment time, and control root resorption.

Acknowledgment

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