Guest Editorial

Clear aligner biomechanical limitations: anchorage and couple (torque) development

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Clear aligners have become increasingly popular in orthodontics as an attractive and removable alternative to traditional fixed-appliance treatment. However, the effective implementation of torque and the maintenance of adequate anchorage pose challenges for clear aligner therapy. Torque in orthodontics,[1–4] which involves rotational force necessary for root movement, and anchorage,[5] which refers to stability and prevention of unwanted tooth movement, are critical parameters in orthodontic treatment and require careful consideration of biomechanics.

Traditionally, torque is achieved by applying a couple, which consists of opposite forces with equal magnitudes in different, parallel lines of action.[3] Fixed appliances can generate high-force loads concentrated around bracket slots, enabling effective torque development in all dimensions. In contrast, clear aligners have struggled to generate comparable couples required for torque implementation during treatment. In addition, anchorage is better controlled with fixed appliances due to their relatively rigid nature and strong adhesion to neighboring teeth, allowing this trait to manifest itself. Clear aligners face challenges in providing optimal anchorage due to the material from which they are made, their removable nature, and the absence of fixed attachments, leading to potential anchorage loss and unwanted tooth movement. Over the years, using different conventional and, later, optimized attachments partially to resolve these problems did not solve the anchorage or the couple construction problems.[6]

In orthodontics, force application is categorized based on the number of force points involved: one-, two-, and three-point force applications, each yielding distinct tooth movement outcomes.[7,8]

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One-point force application involves applying a force vector away from the tooth's center of resistance (Cres), resulting in uncontrolled tipping. This movement causes the apex and incisal edge to move in opposite directions while the tipping center of rotation (Crot) is near, but apical to, the Cres. In extremely rare cases, when the force vector passes through the Cres, it can result in bodily movement, including true intrusion and extrusion, two movements that aligners cannot accomplish. Tipping by itself can produce only relative, but not true, intrusion and extrusion.

Two-point force application, known as a "couple," involves the intentional application of opposite forces equal in magnitude to generate torque. This primary torque refers to rotational movement around the couple's center, depending on how the appliance is restrained, primarily affecting the apex (root movement). It is important to note that torque is typically related to a short-term movement performed during the finishing phase of orthodontic treatment in the anterior region. However, torque is used in almost all stages of fixed appliance orthodontics, from leveling and alignment, opening and closing spaces, intrusion and extrusion, up to the finishing stage, where minute, exact movements are needed. Most of the time, the couple expresses itself without any specific involvement of the orthodontist. It is "all included" in the edgewise system itself.

Three-point force application combines tipping and couple movements, such as the closure process of an extraction space in fixed-appliance treatment. This movement pattern, known in the profession as "walking," is usually achieved by applying a one-point force application that initially tips the crown backward and the root forward until a two-point force application, a couple within the bracket slot, develops. This secondary, developmental couple helps upright the tooth by moving the apex to the point at which new tipping is built. However, this movement pattern has not been replicated with removable appliances, including clear aligners. Therefore, despite the advantages offered by clear aligners, such as improved esthetics, hygiene, and patient comfort, their biomechanical limitations in torque implementation and anchorage control need to be addressed.

Existing attempts to improve material properties, aligner design, and auxiliary appliances or attachments have not yielded significant improvements.[9,10]

Orthodontic torque requires continuous and long-lasting, high-level force application in the same location and relies on higher loads from neighboring teeth for anchorage.[3] Removable appliances inherently lack the stability and firmness required to maintain a couple over an extended period.[11] In addition, the absence of fixed attachments between the aligners and the teeth prevents the development of adequate anchorage. Despite advancements in material stiffness and the use of attachments, the removable nature of aligners hinders their ability to consistently generate the desired torque, even with the best artificial intelligence systems whenever used.

Accurate determination and measurement of torque changes require a comparison of short-term, consecutive lateral cephalograms or dedicated cone-beam computed tomography scans before and immediately after the designated torque movement with reference points dedicated to measuring this movement change.[3,4] Measuring tooth inclination changes during full or long-term treatment periods does not measure orthodontic torque-dedicated movements. Measuring buccal segment torque changes is beyond the scope of this article.

Although the Raintree EssixR appliance (the forefather of clear aligners) claimed to engage torque as a possible trait, no supporting randomized controlled trial exists. While graphical representations in textbooks and the media may be convincing, a force system analysis reveals that the ditches in the removable plastic aligners contradict the effective delivery of torque.[12]

In conclusion, it is widely acknowledged within the profession that clear aligners have difficulty delivering orthodontic torque, and this limitation is likely to persist as long as the appliance remains removable. Rigorous scientific research, including well-designed, randomized controlled studies, is crucial to validate biomechanical outcomes and the ability to maintain anchorage in order to establish clear aligners as a reliable alternative to fixed appliances.

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