Biomechanical Limitations of Clear Aligners: The Constraint of Single Point Force Application

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Abstract

The concept of the **Center of Resistance (CRes)** is paramount in defining how a naturally restrained tooth responds to orthodontic loads, typically located near the center of the root. **Fixed Appliances (FA)** utilize artificial restraint (approximately 200,000 MPa) to dynamically shift the CRes location from the root to the bracket slot, which is essential for achieving precise three-dimensional (3D) tooth movement. This shifting is facilitated by the reliable application of a **couple,** two equal, opposite forces acting in separate planes, a mechanism unavailable to removable appliances.

Clear Aligners (CA) and other removable devices are inherently limited to applying a **single force vector** to the crown. This application results predominantly in **tipping** (rotation around the natural CRes in the root), which is the default movement for restrained bodies exposed to such loading. This fundamental biomechanical constraint leads to low clinical efficiency, averaging approximately **50% of programmed tooth movement** across all movement types.

Consequently, specific complex movements are considered **predictably unattainable** or highly unpredictable with CAs. These include **orthodontic torque** (the movement requiring a couple to shift the CRes to the crown), **pure bodily translation,** and **pure intrusion**. Attempts to achieve these movements often result in undesirable tipping or incomplete correction. The inability of CAs to systematically control the CRes position restricts them mainly to complex tipping patterns, necessitating extensive **overcorrection strategies** and multiple sets of aligners to "walk" the teeth toward the desired outcome. This lack of precise control suggests that CAs are unlikely to match the clinical excellence of FA, particularly concerning finishing details and achieving root parallelism.

Keywords

Center of Resistance (CRes), Fixed Appliances (FA), Clear Aligners (CA), Couple, Tipping, Translation, Torque, Intrusion, Root Parallelism.