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In Orthodontic Space Closure, Friction Isn't an Enemy to Be Crushed—It's a Variable to Be Tuned

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Research Article

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Abstract

Background: Friction during orthodontic space closure has traditionally been viewed as an obstacle to be minimized or eliminated.

Methods: This clinical perspective synthesizes biomechanical evidence from in vitro studies, randomized clinical trials, and established orthodontic biomechanics literature to reframe the role of friction in space closure.

Results: In sliding mechanics, low, controlled frictional resistance is not only inevitable but also beneficial for transmitting gentle, biologically compatible forces to the roots while preserving rotational control of anchor units. Complete elimination of friction via loop mechanics does not consistently accelerate tooth movement and may introduce unwanted rotations. Binding—the wedging of the archwire against the corners of the bracket slot—often presents a greater clinical challenge than classical friction.

Conclusions: Friction should be regarded as a tunable biomechanical variable—balanced against anchorage requirements, wire properties, and bracket design—rather than a factor to be indiscriminately minimized. Optimal sliding appears to occur when frictional losses remain within approximately 15–30% of the applied force. These recommendations are grounded in biomechanical principles and supported by contemporary clinical evidence. The future of orthodontic biomechanics lies not in eliminating friction but in defining, measuring, and clinically optimizing it.

Introduction

For decades, orthodontic space closure has been governed by two biomechanical philosophies: friction mechanics (sliding teeth along a continuous archwire) and frictionless mechanics (using closed loops or other wire bends to move teeth without sliding contact). A persistent belief among clinicians and researchers has been that friction is inherently detrimental—that lower friction always produces faster, more physiologic tooth movement. This belief has driven innovations such as self-ligating brackets, coated archwires, and low-friction surface treatments.

However, the clinical reality is more nuanced. As Rossouw noted, friction is a clinical challenge that must be managed efficiently, but it can also be advantageous for providing anchorage [1]. Friction is neither universally harmful nor a variable to be chased to zero without consequences. This article proposes a paradigm shift: **friction should be viewed as a tunable parameter**. Optimal space closure occurs not at the lowest possible friction but at a *controlled, low level of friction* that balances efficient sliding with precise control of tooth position and anchorage. To our knowledge, no previous clinical perspective has explicitly framed friction as a tunable parameter within a target biomechanical range.

The Case Against Indiscriminate Friction Reduction

Zero Friction Does Not Accelerate Closure

Recent evidence challenges the assumption that reducing friction accelerates tooth movement. A 2024 randomized clinical trial by Magdi and colleagues compared friction versus frictionless mechanics for maxillary en-masse retraction and found no clinically significant difference in space closure rate [2]. The frictionless approach did not meaningfully accelerate tooth movement, despite its theoretical advantage of eliminating frictional resistance. This finding suggests that biological patient response and overall force systems may be more critical to efficient tooth movement than friction alone.

Biological Force Is Not Purely Mechanical

The classic force-decay curve in sliding mechanics indicates that a portion of the applied force is lost to friction. Nevertheless, the remaining force is often more continuous and damped than in a frictionless system, where force can fluctuate considerably as the loop deactivates. Low, steady frictional resistance helps avoid sudden unloading of the periodontal ligament, thereby reducing the risk of hyalinization and root resorption [3].

Binding, Not Friction, Is the Primary Challenge

In clinical sliding mechanics, the greatest resistance to tooth movement often arises from **binding**—the wedging of the archwire against the corners of the bracket slot when the tooth tips—rather than from classical friction between the wire and bracket [1]. Articolo and Kusy demonstrated that when clearance disappears and an interference fit develops between the bracket and the archwire, binding emerges as a second component of resistance to sliding, superimposed on classical friction [4]. Binding is exacerbated by large wire-slot angulation, sharp bends, and undersized wires. Efforts to reduce surface friction (e.g., polishing or coatings) have limited effect once binding becomes the dominant component of resistance. The appropriate solution is to control tip and torque.

Friction Can Be Advantageous

Friction is not always detrimental: it can be beneficial for providing anchorage [1]. For example, during maximum anchorage en-masse retraction, slightly increased friction may help limit the mesial drift of posterior teeth, whereas during canine retraction, lower friction may be preferred to facilitate efficient sliding. The clinical challenge lies in harnessing friction where needed and minimizing it where it impedes treatment goals.

Friction as a Tuned Variable: Defining the "Sweet Spot"

If friction is not inherently detrimental, what is its proper role? Clinically, optimal sliding appears to occur when frictional losses remain within approximately **15–30% of the applied force**, allowing effective force transmission while maintaining control. Although this range varies with wire-bracket combinations, it provides a practical reference for clinical tuning. More specifically, the ideal frictional system should:

- Be **low enough** to permit smooth sliding under light forces (approximately 150 g for canine retraction).
- Be **high enough** to prevent sudden tooth tipping and preserve rotational control of the anchor unit.
- Be **predictable and consistent** so that the applied force is reliably transmitted to the root.

This balance is achieved by tuning three families of variables. Rossouw noted that understanding these variables enables the orthodontist to appropriately apply biomechanical principles [1].

Table 1. Variables for tuning frictional resistance in sliding mechanics

Variable Category	Clinical Strategy	Effect on Resistance
Archwire	Use stainless steel; employ round wires for initial sliding, then transition to rectangular wires for torque control. Avoid nickel-titanium during active sliding.	Reduces friction
Bracket	Passive self-ligation reduces variable friction but does not eliminate binding. Use conventional brackets with a low-torque prescription.	Reduces variability
Biomechanics	Maintain low wire-slot angulation; use short-activated elastomeric chains or low-force coil springs. Control tipping.	Primarily reduces binding (the dominant component)

Importantly, these adjustments represent *tuning* choices rather than absolute mandates. Kusy and Whitley quantified that the proportion of applied force lost to friction can range from 12% to 60%, depending on the wire-bracket combination [5]. The clinician's goal is to select combinations that fall at the lower end of this range while preserving adequate control.

Clinical Recommendations for Tuning Friction

The following practical guidelines are offered for sliding-mechanics space closure. These recommendations are based on biomechanical principles and clinical experience rather than on high-level comparative trials.

1. **Do not pursue zero friction.** Do not rely solely on self-ligating brackets or coated wires expecting dramatic acceleration of closure. The evidence does not support this expectation [2].
2. **Control binding first.** Use an archwire that adequately fills the bracket slot (e.g., 0.019 × 0.025-inch stainless steel in a 0.022-inch slot). Keep the archwire as straight as possible between the active

and anchor teeth. As Articolo and Kusy demonstrated, binding dominates resistance once angulation exceeds bracket-wire clearance [4].

3. **Select the force level wisely.** Quinn and Yoshikawa showed that the rate of tooth movement increases proportionally with force only up to a point; beyond that threshold, additional force produces no appreciable increase in movement [6]. Initiating treatment with 150 g of force is recommended, as higher forces increase binding without accelerating movement.
4. **Monitor rotation.** If the anchor molar rotates significantly, consider that friction may be too low or binding too high. Frictional resistance directly influences the effective moment-to-force ratio during sliding mechanics, thereby altering the center of rotation. Controlled friction may help stabilize this ratio, contributing to more predictable bodily movement [7].
5. **Reserve frictionless mechanics for specific indications.** Use loops for large extraction spaces or when maximum three-dimensional control is required (e.g., canine root torque), but recognize that the space closure rate will not be dramatically faster than with well-tuned sliding mechanics [2].

Discussion

The Role of In Vitro Versus In Vivo Evidence

Much of our understanding of friction derives from in vitro studies. Rossouw cautioned that experimental conditions do not always accurately represent the clinical situation, and that frictional forces measured in the laboratory may overestimate those encountered in the oral cavity [1]. Saliva, plaque, the acquired pellicle, corrosion, and food particles all influence friction in ways that are difficult to simulate [1]. Clinically, the forces lost to frictional resistance may be lower than those measured in steady-state laboratory experiments [8]. Nevertheless, the general trends identified in vitro—that stainless steel wires generate less friction than other alloys, that larger wires increase binding, and that angulation dramatically increases resistance—remain valid clinical guides [4].

Future Directions

Future research should aim to quantify in vivo frictional resistance using real-time force sensors or digital orthodontic systems. Such tools would allow clinicians to move beyond theoretical ranges and toward patient-specific friction optimization.

Limitations

This perspective is conceptual and synthesizes existing evidence rather than presenting primary data. The proposed frictional range of 15–30% represents a clinical estimate based on the available biomechanical literature rather than a rigorously validated threshold. Prospective studies are needed to define optimal frictional ranges for specific tooth movements.

Conclusion

Friction in orthodontic space closure should not be indiscriminately minimized. Rather, it is a biomechanical parameter that can be tuned for each patient and each stage of treatment. As Rossouw concluded, "To prevent undesired tooth movement and to ensure optimal tooth movement, friction must be understood and controlled" [1]. The goal is not zero friction but *controlled, low, and predictable* friction—ideally with frictional losses in the range of 15–30% of the applied force. By shifting clinical thinking from "friction is bad" to "friction is tunable," practitioners can achieve more efficient, stable, and biologically compatible space closure. The future of orthodontic biomechanics lies not in eliminating friction but in defining, measuring, and clinically optimizing it.

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