**Asian Journal of Periodontics and Orthodontics**
2022, Volume 2, Page No: 93-105

Available online at: www.tsdp.net

**ISSN: 3062-3499**

**Review Article**

# Cantilevers in Orthodontics: Versatile Applications and Clinical Insights

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**Received:** 03 August 2022; **Revised:** 16 November 2022; **Accepted:** 17 November 2022

## ABSTRACT

This review explores the diverse applications of cantilevers in addressing a range of clinical orthodontic challenges, highlighting their adaptability and effectiveness. Cantilevers are frequently employed in the segmented arch technique, allowing clinicians to manage various problems with predictable outcomes. Their design and configuration enable modulation of both vertical and horizontal force components. A recent advancement is the integration of cantilevers with skeletal anchorage systems. Cantilevers provide a straightforward, statically determinate force system, offering precise control over side effects that typically affect anchor teeth and occlusion. However, improper anchorage management may lead to undesirable effects on the anchoring units. This review emphasizes the significant advantages of cantilevers in complex corrections involving single teeth, tooth segments, or the entire arch, particularly when combined with skeletal anchorage. Due to their simple, customizable design, cantilevers can aptly be described as a versatile orthodontic "multi-tool."

**Keywords:** Cantilevers, Statically determinate system, Orthodontics, Segmented arch technique

**How to Cite This Article:** Plavcan P, Volkmann U, Vartiak L. Cantilevers in Orthodontics: Versatile Applications and Clinical Insights. Asian J Periodont Orthodont. 2022;2:93-105. https://doi.org/10.51847/Kv3DbyRgYh

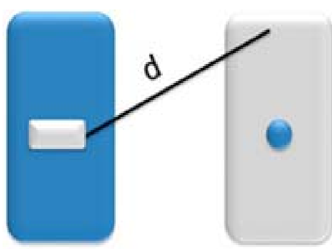
## Introduction

The use of well-defined biomechanical force systems enables predictable and controlled tooth movement in accordance with the principles of equilibrium. The segmented arch technique, first introduced by Charles Burstone in 1962 [1], often offers several clinical advantages over continuous archwires [2]. A solid understanding and application of basic biomechanics can enhance the efficiency of orthodontic appliances, minimize unwanted side effects, and potentially shorten overall treatment duration [3-5]. Cantilevers are frequently employed within the segmented arch technique, and their design allows clinicians to address a variety of clinical challenges with high predictability [6]. When combined with the straight-wire technique for moving isolated displaced teeth, cantilevers help reduce the risk of affecting adjacent well-positioned teeth [7]. In practice, it is generally recommended to avoid connecting severely displaced or impacted teeth to a continuous archwire to prevent undesirable effects. Cantilever systems require less frequent reactivation due to their low load/deflection ratio and extended span between attachment points [8].

Cantilevers are typically fabricated from titanium-molybdenum alloy (TMA), although stainless steel (SS) can also be used. TMA can tolerate greater deflection than SS without permanent deformation, allowing simpler cantilever designs and often saving clinical time. Its stiffness and elastic modulus facilitate controlled force application and customized tooth movement [9]. The configuration and shape of a cantilever can modify combinations of vertical and horizontal forces: curved cantilevers provide simultaneous retraction and intrusion, whereas utility-shaped cantilevers generate protrusive and intrusive forces [10, 11] **(Figure 1)**. Furthermore, the location of activation affects the pattern of force decay over time [12].

**Figure 1.** Different cantilever designs (activated). From the left: deep curve, tip back, and utility arch.

Orthodontic force systems can be classified as either statically determined or statically indeterminate. In a statically determined system, all forces and moments can be calculated from the equations of force and moment equilibrium, making the system highly predictable. In contrast, statically indeterminate systems are less understood, both qualitatively and quantitatively. The cantilever spring represents a simple, statically determined design. It generates a single force at the mesial contact point, while a reactive force of equal magnitude occurs at the distal end in the opposite direction. These two forces create a couple that must be balanced by a reactive moment to maintain equilibrium **(Figure 2)**.

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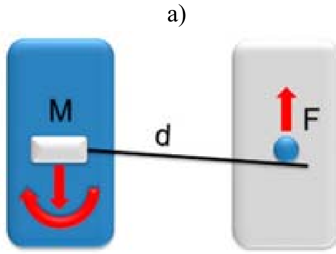



b)

**Figure 2.** Schematic of a statically determinate force system (blue: cantilever anchorage unit; grey: force application point). (a) Cantilever in neutral position, span length (d). (b) Upon activation, the cantilever produces a single force (F) at one end and a force with an associated moment (M) at the other end (red arrows).

Although cantilevers are extremely versatile in orthodontics, their potential is often underrecognized. This review highlights their diverse applications, demonstrating how they can effectively address multiple clinical challenges.

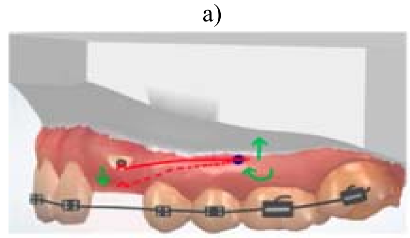
*Anchorage considerations*

Traditional anchorage units generally involve a segment of teeth, which may be reinforced with devices such as a transpalatal arch (TPA). Extrusive vertical forces can be counteracted using high-pull headgear, while natural occlusal contacts can also provide partial resistance [13]. A contemporary approach involves integrating cantilevers with skeletal anchorage systems, including temporary anchorage devices (TADs) or miniscrews. Several studies describe the use of TAD-supported one-couple force systems, which allow for precise control of unwanted effects typically seen on anchor teeth and occlusion.

While skeletal anchorage does not eliminate the need for careful biomechanical planning, it can simplify certain treatment steps. This is especially advantageous for isolated tooth movements in patients who do not require full-arch orthodontics. In managing impacted teeth, placement of fully fixed appliances can be delayed until the impaction is resolved and ankylosis is excluded [14]. Cantilevers attached directly to TADs act as direct anchorage; matching the cantilever wire dimensions to the screw slot helps minimize wire play [15]. When used as indirect anchorage, TADs stabilize the anchorage segment—for instance, supporting a TPA to prevent molar side effects [15].

Correct positioning of TADs is critical: aligning them along or parallel to the dental arch reduces torsional stress, whereas perpendicular placement relative to the long axis of the dentition (buccal or palatal cortex) can generate clockwise or counterclockwise moments, increasing the risk of screw failure [16] **(Figure 3)**.

a)



b)

**Figure 3.** a) A TAD aligned along or parallel to the dental arch experiences minimal torsional stress. b)

When positioned perpendicular to the tooth axis, the TAD is subjected to clockwise or counterclockwise torquing forces (red: cantilever, green: applied force and moment).

*Impacted teeth*

Orthodontic management of ectopic or impacted teeth is among the most demanding aspects of treatment. Cantilevers, when used in a statically determinate system, allow precise control over the force vector to suit the specific clinical scenario. For canines impacted buccally, forces are typically applied to extrude the tooth while directing it mesially or distally as needed. Palatally impacted canines, by contrast, require a combination of extrusion and buccal displacement. In cases where both canines are impacted, simultaneous bilateral traction can be applied [17–19].

Applying gentle, physiologically compatible forces minimizes complications and preserves bone health. Extrusive forces in the range of 25–30 cN are generally sufficient to move the canine across a wide activation span [18, 20]. To avoid creating unwanted rotational moments, the cantilever should attach to the canine at a single point; if attached via the bracket slot, a compensatory toe-in bend may be incorporated [8]. Vertical tube-supported cantilevers also provide an effective alternative for canine extrusion, as previously described by Vijayashree and Pai [21]. Using auxiliary anchorage devices, including TADs, helps reduce stress transmitted to adjacent teeth [22]. Accurate control of both the direction and magnitude of force is essential, as poorly managed extrusion can lead to root resorption in neighboring teeth or induce undesired rotations [23].

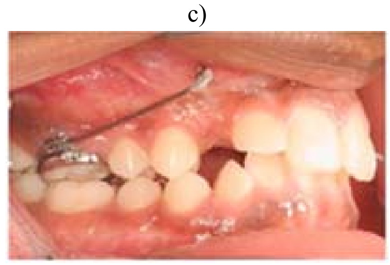
*Buccal impaction*

For buccally displaced canines, a single extrusive force can be efficiently generated using a 0.017″ × 0.025″ TMA cantilever. This spring is anchored in the auxiliary tube of the first molar and connected to the canine with a single-point attachment **(Figure 4)**.

a)

a)

c)



d)

e)

f)

**Figure 4.** Management of bilateral maxillary canine impactions: the right canine is buccally displaced, while the left is palatally positioned. For the right canine, a 0.017 × 0.025″ TMA cantilever is activated to provide extrusion. For the left canine, the cantilever is anchored in the auxiliary tube of a maxillary molar and adjusted to achieve both extrusion and buccal movement.

Katiyar and colleagues proposed a cantilever design incorporating a closing loop for buccally impacted canines, positioned mesial to the first molar. Activation of this loop can also facilitate distal movement of the canine when required [24] **(Figure 5)**. Once the canine is aligned within the arch, a box loop can be employed to refine first- and second-order angulations while maintaining controlled vertical eruption [25].

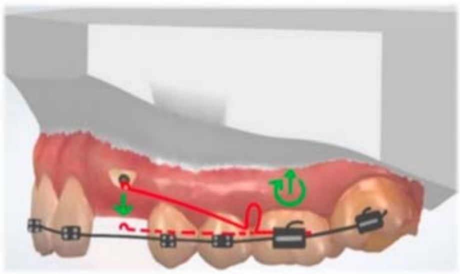
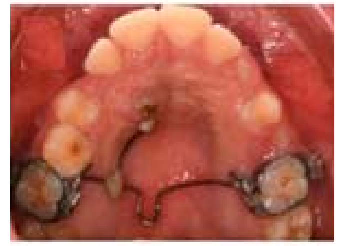


**Figure 5.** Cantilever with an incorporated loop used to extrude a buccally impacted canine (red: cantilever; green: applied force and moment).

*Palatal impaction*

The management of palatally impacted canines typically requires two sequential movements: first, extrusion from the palatal position, and then buccal translation into the arch. One strategy involves inserting a cantilever into the buccal auxiliary tube of a molar to exert force on the impacted canine [18, 26, 27]. To avoid interference with occlusion, the cantilever may instead be connected to the lingual sheath of the molar [8, 18], or attached to a welded extension on a transpalatal arch (TPA) **(Figure 5)**.

These approaches do not automatically provide reinforced anchorage. Prolonged traction without proper anchorage may lead to unwanted effects such as tipping or intrusion of the molars. Using a TPA can help stabilize the anchorage unit and minimize these side effects **(Figure 6)** [28]. Nakandakari *et al.* described a two-cantilever method: one cantilever welded to the TPA provides vertical extrusion, while a second cantilever from the auxiliary molar tube directs the canine buccally [28]. Tepedino and colleagues reported a similar technique using a stainless-steel cantilever soldered to the TPA, functioning like a torsion spring. The force delivered depends on wire diameter, wire length, and the degree of activation, with loops introduced to modify wire length as needed [29]. Notably, their findings suggest that variations in facial type or muscular activity do not significantly affect the forces applied for palatal canine traction [20].



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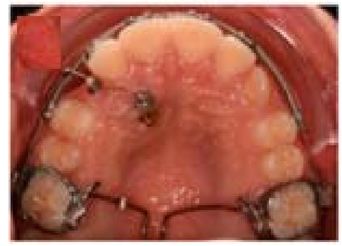

b)

c)

**Figure 6.** Management of a palatally impacted right maxillary canine. a) Extrusion using a 0.017 × 0.025″ TMA cantilever attached to the welded sheet of a TPA. b) Cantilever inserted into the auxiliary tube of an upper molar to achieve both extrusion and buccal movement. c) Canine successfully aligned into its final arch position.



Temporary anchorage devices (TADs) can function as either direct or indirect anchorage points. Thebault *et al*. and Heravi *et al*. reported a technique in which a cantilever is connected to two TADs for direct traction of impacted canines. Using two miniscrews mitigates rotational forces on the screws during activation and deactivation, reducing the likelihood of failure [14, 15]. Annarumma and colleagues investigated canine traction using a double miniscrew-cantilever setup, employing different cantilever designs to achieve extrusion, distalization, and optimal torque control. This skeletal anchorage strategy enables tooth movement without placing stress on the posterior teeth, making the segmented approach an efficient option for treating impacted canines [30].

Cantilevers can also be attached simultaneously to both a tooth-based anchorage unit and a TAD, forming a multi-point support system. Positioning the cantilever in the molar auxiliary tube minimizes moments acting on the screw head [15]. When used for indirect anchorage, the TAD stabilizes the anchorage segment while the cantilever delivers force from the auxiliary tube. This arrangement helps prevent undesired effects on neighboring teeth **(Figure 7)**.


**Figure 7.** Panoramic radiograph of a 16-year-old showing an ectopic left maxillary canine (tooth 23) with minimal resorption of tooth 63. a) The canine is palatally impacted. Because the patient preferred to maintain the existing diastemas and overall smile aesthetics, a sectional appliance was chosen to reposition tooth 23 without altering the rest of the dentition. b) A 0.017 × 0.025″ TMA cantilever, inserted into the auxiliary molar tube, was activated to achieve both extrusion and buccal translation of the canine. A TAD provided indirect stabilization of the molar to support the anchorage unit. c) The canine is successfully aligned into its target position within the arch.

After alignment, correcting the buccolingual torque of the canine is often necessary. Gandini *et al*. introduced a method to adjust the buccolingual inclination, allowing substantial root movement with minimal crown displacement. In this technique, a 0.017 × 0.025″ TMA cantilever is inserted into the canine bracket, bonded on the palatal or lingual surface, and connected at a single point to a transpalatal bar or lingual arch. Depending on the tooth's starting position, this method can achieve proper inclination in approximately 5–8 months [31].

*Correction of deep bite*

A three-piece intrusion arch is constructed from separate anterior and posterior segments joined by two cantilevers. Activation of these cantilevers produces controlled intrusion of the anterior segment **(Figure 8)**.

a)

b)

**Figure 8.** Three-piece intrusion arch. Deep curve shape cantilevers activated for anterior segment intrusion cantilevers: a) activated, before ligation; b) ligated distally to lateral incisors.

The three-piece intrusion arch produces a relatively low load–deflection response, typically under 10 cN/mm, due to the extended span between the molar auxiliary tube and the incisor brackets. When the force is applied perpendicular to the occlusal plane, it can pass near the center of resistance of the incisors, assuming proper attachment placement and no unintended flaring [32]. Employing light, continuous forces allows controlled intrusion with minimal impact on posterior anchorage teeth. Excessive force increases the risk of root resorption without accelerating tooth movement, so force levels should remain as low as possible. The optimal force depends on the number and size of teeth in the intruded segment; for example, approximately 60 cN is suitable to intrude four upper incisors [32]. Van Steenbergen *et al*. found that applying 10–20 cN per maxillary incisor is sufficient, and increasing the force to 40–80 cN did not significantly change intrusion rate, posterior extrusion, or intermolar width [13]. Burstone emphasized that anchorage control relies on low-force application combined with a rigid posterior segment, such as a lingual arch or transpalatal arch [32].

Intrusion combined with incisor retraction is especially beneficial in patients with increased overbite and overjet, such as those requiring perio-orthodontic treatment. Melsen *et al*. analyzed force systems generated by stainless steel and TMA cantilevers with eccentrically placed helix loops, noting that three-piece intrusion mechanics allow lateral displacement of the force application point, bringing the line of action closer to the incisors' center of resistance [33]. Shroff *et al*. proposed a three-piece base arch with Class I elastics for cases of deep bite with flared incisors, using bilaterally placed tip-back springs made from 0.017 × 0.025″ TMA to deliver intrusive forces [34].

Use of mini-implant-supported three-piece Burstone arches has demonstrated effective intrusion of flared maxillary incisors with minimal root resorption. Incorporating TADs into the system addresses limitations of traditional anchorage, with additional distal-directed force helping prevent implant loosening [35]. Mini plates have also been employed as cantilever attachment points for anterior intrusion, as described by Thebault *et al*. [15].

*Anterior open bite*

In some patients, anterior open bites can be corrected by selective dental extrusion, although stability during retention must be considered. Kuhlberg described a system using two cantilevers attached to the anterior segment and anchorage unit, acting in opposition to a three-piece intrusion arch, with a passive TPA to prevent third-order molar movements [36]. Wilmes *et al*. introduced the Mousetrap appliance for molar intrusion **(Figure 9)**, where lever arms connected to two anterior palate mini-implants deliver controlled intrusive forces. A TPA prevents molar tipping, and the distal ends of the lever arms remain above the molars' centers of resistance during deactivation, allowing continuous downward force application [37].

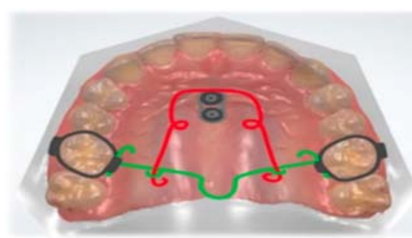

**Figure 9.** Mouse trap appliance. Lever arms connected to TADs, activated for molar intrusion (red). Transpalatal arch (green).

Flieger *et al*. introduced an appliance similar in function to the Mousetrap, with a key distinction in the placement of two Jet Screws. These screws were positioned at approximately halfway along the line from the palatal raphe to the palatal cusp tip of the first premolar. Posterior intrusion was achieved using distally extended cantilevers made from 16 × 22 stainless steel wire, which connected the screws to the maxillary molars [38]. Nojima *et al*. reported an alternative approach for open bite correction combining cantilevers with skeletal anchorage. In their technique, TADs were placed both in the mid-palatal region and on the buccal alveolar bone between the first molar and second premolar. On the palatal side, a 0.018 × 0.025″ TMA transpalatal arch with tear-drop loops transmitted intrusive forces from the mini-implant to the molar palatal tubes. Buccally, a 0.018 × 0.025″ TMA cantilever linked the buccal TAD to the molar auxiliary tube to deliver controlled intrusion [39].

*Single-tooth intrusion*

Intrusion of individual teeth can be effectively achieved using statically determinate mechanics. Studies indicate that about half of patients presenting with deep bite exhibit overerupted mandibular canines [40]. Caballero *et al*. investigated the use of cantilevers for canine intrusion in a finite element study. The cantilever was anchored in the molar auxiliary tube and applied to the labial surface of the mandibular canine bracket **(Figure 10)**. Because the force is applied labially, a significant labiolingual component is generated. Incorporating a 6° toe-in bend effectively prevents buccal or lingual crown tipping, achieving nearly pure intrusion [7].

For optimal results, it is recommended to attach the cantilever to the occlusal surface of the canine bracket, as insertion into the bracket slot can generate an undesired couple [41]. Applying force from the lingual side allows intrusion while maintaining the buccolingual inclination. The precise angle of the toe-in bend should correspond to the canine cusp height [42]. Similar mechanics can be applied to maxillary canines. In cases where an auxiliary molar tube is unavailable, the cantilever can be placed into a cross tube and ligated to the canine bracket [43].

Chandhoke *et al*. described the use of a cantilever anchored to two buccal TADs for intruding an overerupted second molar. The transverse stability during intrusion was maintained using a transpalatal arch, and the molar was successfully intruded without any buccal tipping [16].

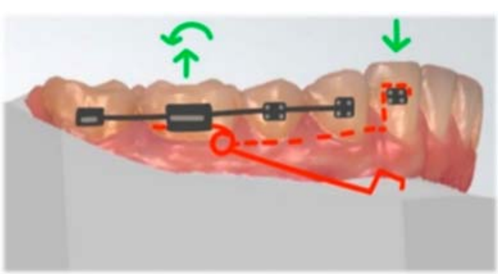

**Figure 10.** Cantilever activated for canine intrusion, placed on the top of the mandibular canine bracket (red: cantilever, green: force and moment).

*Space closure*

Choy *et al*. [44] introduced a determinately controlled system for retracting teeth following extractions. The appliance combines rigid passive anchorage segments with active retraction springs. The anterior and buccal anchorage units are fabricated from stiff stainless-steel wire and reinforced with a transpalatal arch to enhance stability. A hook extends distally from the anterior stabilizing arch, positioned roughly 6 mm above the canine bracket slot. Retraction is accomplished using a cantilever arm made of 0.017 × 0.025″ TMA wire, inserted into the molar tube. The cantilever is ligated to the anterior hook, allowing controlled force transmission. Due to its low load–deflection characteristics, the cantilever delivers a steady force throughout activation, generating 163 cN at full activation with a load–deflection rate of 6 cN/mm [44].

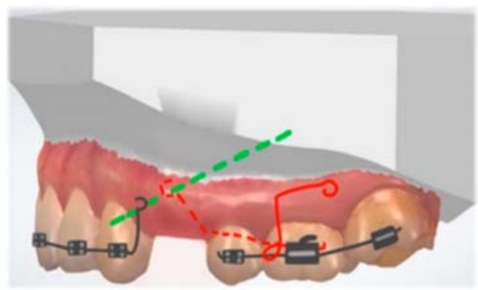

**Figure 11.** Statically determinate retraction system for space closure. Cantilever (red) is activated for anterior segment retraction (green: line of action).

*Occlusal cant*

Distinguishing between an incisal cant and an occlusal cant is essential because they require different treatment strategies. Incisal cants can generally be addressed using precisely controlled, determinate force systems, whereas correcting an occlusal cant often presents greater complexity [45]. In growing patients, selective eruption of the buccal segments can help level the occlusal plane, while in adults, surgical intervention is frequently necessary. Deluke *et al*. introduced a method to correct a lower incisal cant using a 0.017″ × 0.025″ TMA cantilever, extending from the first molar auxiliary tube to the main archwire between the central and lateral incisors. Sectioning the main archwire allows the anterior segment to intrude unilaterally [45].

Musilli *et al*. described a cantilever modeled on a Ricketts utility arch with modified distal hooks connected bilaterally to the continuous archwire between the second premolars and first molars. This spring design induces intrusion on one side of the anterior segment and extrusion on the opposite side, enabling cant correction without producing steps between canines and lateral incisors [46]. Chandhoke *et al*. reported using skeletal anchorage in combination with a cantilever to simultaneously correct a mandibular cant, close lateral open bites, and adjust transverse discrepancies. In this single-couple system, the applied force tilts the mandibular arch, reduces canine overjet, and corrects the dental midline [16]. According to van Steenbergen and Nanda, when addressing a posterior occlusal plane cant, a cantilever attached to the anterior segment can upright the posterior segment. Side effects may include extrusion of buccal teeth and unilateral anterior intrusion, with the tip-back moment on the buccal segment helping to flatten the occlusal plane [47].

*Asymmetry and midline adjustment*

Achieving proper midline alignment is crucial for both aesthetics and functional occlusion [48]. Cantilevers are particularly effective in cases where apical base discrepancies require uprighting of tipped incisors and adjustment of their axial inclinations [49]. If midline deviation is caused by simple tipping of lower incisors, applying force at the crown may suffice. For bodily tooth movement, the cantilever should be connected to a passive loop extended toward the incisor's center of resistance [36].

Fiorelli *et al*. proposed a technique combining deep bite correction with midline adjustment. Two cantilevers worked on the anterior segment: one applied lateral intrusive force to the maxillary lateral incisor, while the contralateral cantilever counteracted tipping through horizontal force [48]. Similarly, Mittal *et al*. designed a system where the anterior segment, extended vertically to approximate the center of resistance, is displaced using a 0.017″ × 0.025″ TMA cantilever bent buccally and secured to a loop with an elastomeric chain. Activation produces controlled translation, efficiently correcting the midline [50].

Bilinska and Dalstra's experimental study highlighted that cantilever shape influences both vertical and horizontal force vectors. Deep-curve cantilevers generate retraction with lateral force, whereas utility-shaped cantilevers induce protraction and medial force. By placing different cantilever shapes on either side of the anterior segment, transverse forces can assist in midline correction **(Figure 12)** [11].

**Figure 12.** Asymmetric cantilever activation: activation of utility arch (right side of typodont) and deep curve cantilever (left side of typodont), resulting intrusion and displacement of anterior segment (before: pink; after: blue).

*Molar uprighting*

One commonly used approach for uprighting molars relies on segmented mechanics. In this method, a cantilever is anchored in the molar tube and attached to the anterior segment, producing extrusion and clockwise rotation of the molar while simultaneously intruding the anterior teeth. To better manage the vertical forces, a double cantilever configuration can be employed **(Figure 13)**. This setup generates only two opposing moments: one acting on the molar and the other on the anterior segment, allowing predictable control of tooth movement [51].



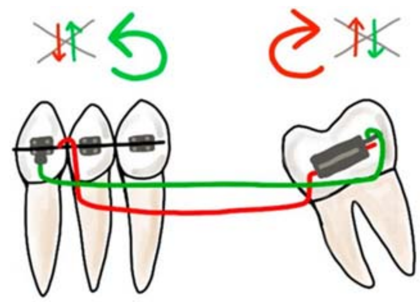

**Figure 13.** Double Cantilever Mechanics

In a double cantilever setup, one cantilever (red) extends from the molar to the anterior teeth. This generates extrusion and clockwise rotation of the molar while intruding the anterior segment (red arrows). To manage vertical forces, a second cantilever (green) is placed from the anterior tube distally toward the molar. This generates molar intrusion and a counter-clockwise moment, accompanied by slight extrusion of the anterior teeth (green arrows). The opposing forces neutralize each other, producing only two primary moments on the molar and anterior segment.

Uprighting mesially tipped molars is a critical step in achieving successful periodontal and restorative outcomes [52]. Khouw *et al*. introduced the helical uprighting spring, inserted into the molar tube and connected to a continuous archwire spanning the canine and premolar. The system generates an extrusive force with a distal moment to upright the molar and induce lingual crown tipping. The anchorage unit experiences reciprocal effects, such as premolar intrusion and lingual tipping [52]. Kojima *et al*. reported that incorporating a lingual bend in the cantilever reduces stress on anchor teeth, potentially minimizing unwanted side effects [53].

Ma *et al*. described uprighting techniques for impacted second and third molars. Initially, a three-loop spring distalized the impacted third molar. The second molar was then uprighted using a cantilever inserted into the impacted molar's buccal tube, with the free end hooked to the main archwire. This approach not only repositions the molar but also promotes bone apposition distal to adjacent teeth, reducing the risk of nerve injury during subsequent extraction [54, 55]. Alessandri Bonetti *et al*. proposed a cantilever-assisted "orthodontic extraction" for third molars. Activation extrudes the molar, increasing the distance from the mandibular canal and providing a safer surgical approach [56].

"Kissing molars," where two mandibular molars are impacted crown-to-crown with roots oriented in opposite directions, are typically managed with extraction. Barros *et al*. described a conservative approach using torqued cantilever mechanics to upright and preserve these molars. The torque arm applies a mesiodistal moment to the roots, enabling uprighting primarily through root movement. A long cantilever arm provides a low load–deflection rate, generating a controlled force system suitable for root repositioning [57, 58].

Morita *et al*. evaluated separate uprighting methods for mesially tipped mandibular first and second molars. For the first molar, the cantilever's distal end was twisted to create the required uprighting moment, with the mesial end anchored to a TAD to counteract extrusion. The second molar was uprighted using a nickel–titanium archwire with two step bends, applying a compressive force to tip the molar distally [59]. Chandhoke also described TAD-supported uprighting springs for mesially tipped lower molars, with the cantilever stabilized on the TAD to prevent unwanted moments and screw failure [16].

Musilli *et al*. demonstrated molar uprighting using a cantilever attached to a TAD in the retromolar region. This method delivers a controlled moment and intrusive force directly to the molar without the need for additional appliances [51]. When employing a long cantilever from the anterior segment, placing a TAD mesial to the molar allows vertical force control, combining the advantages of the classic double cantilever system with improved patient comfort [51].

*Dental transposition*

Treatment planning for dental transpositions must be individualized to minimize potential risks and undesirable effects. In cases of maxillary canine–first premolar transposition, the canine is often displaced mesiobuccally between the first and second premolars, while the first premolar is tipped distally and shifted mesiopalatally [60]. Laino *et al*. demonstrated a segmented approach for managing tooth impaction and transposition using multiple cantilever designs [2].

Capelozza Filho *et al*. reported the correction of unilateral maxillary canine–first premolar transposition using a 0.019 × 0.025″ TMA cantilever to distalize and palatally reposition the first premolar. Once the premolar was properly aligned, the maxillary canine was mesialized into its final position with controlled torque [61]. Lorente *et al*. treated incomplete canine–first premolar transposition with a cantilever attached to an auxiliary band tube, reinforced by a transpalatal arch (TPA). The cantilever guided the canine mesially and apically toward the widest region of the alveolar ridge, reducing the risk of periodontal recession [62].

For cases involving canine–lateral incisor transposition, the canine was extruded buccally using a cantilever while the lateral incisor was mesialized to its proper arch position. Cantilevers with incorporated loops enabled controlled tooth movement while maintaining anchorage stability [63]. Fu *et al*. described a simplified system using a cantilever anchored to a TAD to correct an ectopic central incisor and a transposed canine–lateral incisor. This method allowed efficient movement of the transposed teeth without periodontal compromise, with the skeletal anchorage providing sufficient stabilization [64].

*Single-tooth extrusion*

Cantilevers in combination with skeletal anchorage can also be employed for forced eruption in cases of subgingival defects, including root fractures or cervical caries. Noh and Park described a system in which a cantilever connected to a TAD delivered extrusion forces directly to the root of a lateral incisor along its long axis. This approach eliminates the need to bond brackets on adjacent teeth, allowing isolated correction of the affected tooth **(Figure 14)** [65].

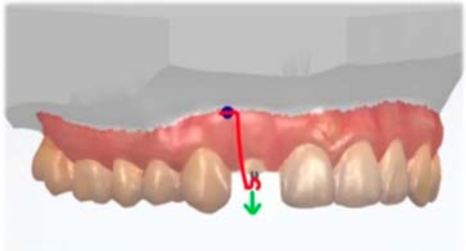

**Figure 14.** A cantilever (red) anchored to a TAD (blue) delivers an extrusive force (green) aligned along the long axis of the tooth.

Kumar *et al*. described a combined orthodontic–prosthetic approach for treating complex horizontal root fractures in the mandibular lateral incisor and first premolar. In cases with highly mobile coronal fragments, a combination of endodontic therapy, decoronation, and orthodontic extrusion allows for predictable restoration of both function and aesthetics. After performing root canal therapy, the lateral incisor was extruded using a 0.017 × 0.025″ TMA cantilever, anchored between the molar and the root post. Once proper extrusion was achieved, the crown was restored. For the first premolar, a 0.014″ NiTi helical coiled wire was used between the canine and molar, with the helix tied to the post using a ligature. Both teeth were stabilized for eight weeks prior to final prosthetic reconstruction [66].

*Molar distalization*

Distal movement of molars is often indicated for the non-extraction correction of Class II malocclusions. Utilizing skeletal anchorage enables controlled molar repositioning while limiting unwanted effects on neighboring teeth. Vilanova *et al*. reported a system where a miniscrew was inserted buccally between the roots of the second premolar and first molar. A 0.014″ stainless-steel cantilever was engaged in the molar tube, and the TAD was connected to the cantilever via a 200 g nickel–titanium closed-coil spring **(Figure 15)**. This setup applies force close to the molar's center of resistance, allowing bodily distalization with minimal tipping or rotation [67].

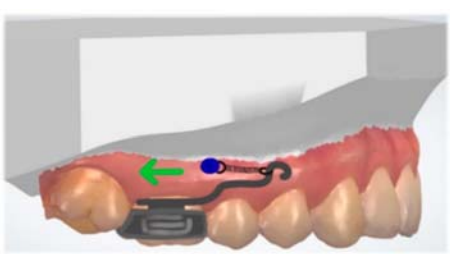

**Figure 15.** Unilateral molar distalization with cantilever connected to the TAD with a closed-coil spring (green: force).

This review examined the diverse applications of one-couple cantilever systems, encompassing both conventional mechanics and approaches integrating skeletal anchorage. Cantilevers offer substantial advantages in managing the movement of single teeth, tooth segments, or even the entire dental arch, while minimizing undesired effects on adjacent teeth. Incorporating temporary anchorage devices (TADs) further enhances anchorage stability and simplifies complex treatment procedures, broadening the range of achievable tooth movements.

Advances in digital technology have the potential to further optimize cantilever design and treatment efficiency. Over the past decade, interest in robotic wire bending and CAD/CAM customization of orthodontic appliances has grown significantly [68]. Cantilevers can now be digitally designed and shaped by robotic systems, reducing chairside adjustments while enhancing precision. Liu *et al*. described a system combining task and motion planning for a robot to bend metal wires into complex three-dimensional geometries, achieving high accuracy and reproducibility [69].

Additive manufacturing is also gaining traction in modern orthodontics. Three-dimensional (3D) printing of orthodontic devices, including distalizers and auxiliary components, allows the creation of precise, biocompatible parts using metals like beta titanium or photopolymers [70-73]. Future applications could include 3D-printed cantilevers with mechanical properties comparable to TMA alloys, potentially available in tooth-colored or transparent forms to improve aesthetics. Biocompatibility assessments indicate that 3D-printed resins perform similarly to conventional materials [74]. While chairside wire bending remains fast and cost-effective, the integration of digital and additive technologies offers promising opportunities for refining cantilever-based treatment.

## Conclusion

When applied with a solid understanding of biomechanics, cantilevers provide a highly predictable and controllable force system capable of addressing a wide range of orthodontic challenges. Their simplicity, adaptability, and versatility make them a reliable "multi-tool" for both routine and complex orthodontic interventions.

**Acknowledgments:** None

**Conflict of Interest:** None

**Financial Support:** None

**Ethics Statement:** None

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