RESEARCH PAPER

MOLAR DISTALIZATION IN CONTEMPORARY ORTHODONTICS: EVOLUTION, BIOMECHANICS, APPLIANCE SYSTEMS, SKELETAL ANCHORAGE AND CLINICAL DECISION-MAKING -A Review

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Abstract-

Molar distalization is a non-extraction strategy for correcting dental Class II relationships and regaining arch length when the maxillary posterior dentition is positioned mesially and the facial profile permits space creation by posterior tooth movement. The evolution from extraoral headgear to intraoral non-compliance appliances and, more recently, skeletal-anchorage-supported systems reflects a continuing attempt to increase treatment efficiency while reducing anchorage loss and unwanted dental effects. This review synthesizes the historical development, indications and contraindications, classification, biomechanics, and clinical effects of major molar distalization modalities described in the supplied literature. Skeletal anchorage has shifted the biomechanical paradigm by allowing force delivery from relatively stable intraosseous anchorage. Clinical and finite-element evidence in the review suggests that palatal skeletal anchorage can improve control of bodily molar movement and reduce reciprocal anterior effects compared with conventional dental anchorage. However, the magnitude and quality of distalization remain dependent on growth status, second-molar eruption, vertical pattern, available posterior space, force vector, anchorage design and appliance selection. Clinical practice should prioritize diagnosis-based selection, control of line of force relative to the molar center of resistance, sequential or en-mass movement according to treatment objectives, and active management of anchorage and retention.

Keywords: molar distalization; Class II malocclusion; non-extraction orthodontics; skeletal anchorage; mini-screws; Pendulum; Distal Jet; headgear; biomechanics; anchorage control.

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Introduction-

The correction of sagittal discrepancies has traditionally involved a choice among growth modification, dentoalveolar compensation, extraction and distal movement of the posterior dentition. The clinical appeal of molar distalization lies in its ability to create arch space and improve a Class II molar relationship without necessarily removing otherwise healthy premolars. The modern development of non-compliance distalization arose largely from the limitations of extraoral therapy-headgear can be effective, but treatment success is influenced by wearing time, aesthetics and patient cooperation. This stimulated the development of intraoral distalizers and, subsequently, skeletal anchorage systems that allow the clinician to control the force system more directly. [1–3]

Distalization may be defined as posterior movement of terminal molars to gain space within the dental arch. The amount of space generated is related to the net distal displacement of the posterior teeth, although the clinical space gained is not necessarily equivalent to molar movement because reciprocal anchorage loss and mesial movement of premolars or incisors may contribute. The review identifies the mixed-dentition period, particularly before eruption of the second permanent molars, as a favorable period for distalization because moving one erupted molar is generally easier than moving both first and second molars simultaneously. [1]

The contemporary significance of distalization extends beyond simple correction of a Class II molar relationship. Posterior movement may assist decrowding, facilitate anterior retraction, correct unilateral Class II subdivision, regain space after premature loss of deciduous molars, and provide a non-extraction option in selected patients with a favorable facial profile. At the same time, distalization is not a substitute for comprehensive diagnosis. A patient with skeletal Class II primarily caused by mandibular retrusion, a high-angle pattern, severe sagittal discrepancy, marked vertical excess or inadequate posterior space may not be an appropriate candidate for isolated molar distalization. Appliance should be selected based on force system that can meet the individual patient's sagittal, vertical and anchorage requirements with the fewest unwanted effects.

Historical evolution of molar distalization-

The history of molar distalization parallels the broader development of orthodontic anchorage. Early extraoral appliances approach established that posterior teeth could be displaced distally by forces generated outside the oral cavity. The development from early head-cap and headgear concepts through the Kloehn cervical headgear and subsequent refinements in face-bow design were used for extra-oral forces. Headgear offered an important advantage: the anchorage source was independent of the dental arch. However, dependence on patient cooperation remained a major limitation. [1,2]

The next major transition occurred with intraoral appliances. Repelling magnets, superelastic nickel-titanium coil springs, the Jones Jig, Pendulum, K-loop and Distal Jet were introduced to provide distalizing forces without the visible external component of headgear. Their popularity reflected a practical advantage that many could be used with limited or no active patient compliance. Comparative studies summarized in the source document showed that intraoral systems can achieve useful distal movement in shorter periods than traditional extraoral therapy, but the reciprocal effects on the anchorage unit remained an important biomechanical problem. [4–14,20]

The introduction of skeletal anchorage represented a further conceptual change. Rather than transferring the reaction force to teeth, mini-screws or miniplates can provide an intraosseous anchorage source. This allows the distalizing force to be applied closer to the desired line of action and, in suitable designs, permits distalization of individual teeth, posterior segments or the entire maxillary arch. The literature summarized in the document includes bone-anchored Pendulum systems, mini-screw-supported Distal Jet appliances, interradicular mini-screw systems, palatal plates and more recent hybrid approaches. [23–28,33–40]

Recent developments have emphasized not only whether distalization can be achieved, but how the tooth moves. The clinical objective has progressively shifted from simple crown movement toward controlled bodily translation, root control, intrusion where indicated, and minimized reciprocal movement. Finite-element studies cited in the source document similarly suggest that the location of skeletal anchorage and the direction of force influence the distribution of displacement and stress. This evolution supports a modern definition of successful distalization as controlled three-dimensional posterior movement rather than a numerical increase in distal molar position alone. [38,50,53]

Indications and contraindications-

Appropriate case selection is the foundation of successful molar distalization. Cases like non-extraction correction of dental Class II relationships, minimal arch-length discrepancy, Class I skeletal pattern, good facial aesthetics, mild crowding, unilateral Class II subdivision, mesial migration of the maxillary first molar following premature deciduous molar loss, and cases in which second-molar extraction is planned or the second molar has not erupted as important indications. These indications share a common feature: the principal problem is dentoalveolar rather than a severe underlying skeletal discrepancy. [1]

There are several situations in which distalization should be approached cautiously or avoided. High-angle patients, skeletal Class II or Class III discrepancies requiring correction of the basal relationship, skeletal or dental open bite, severe arch-length discrepancy, excessive lower anterior facial height and inadequate posterior space are unfavorable situations. Distalization may also be inappropriate when a Class II relationship is largely produced by mandibular retrognathism rather than maxillary dentoalveolar protrusion. In such cases, moving the maxillary molars distally may correct the molar relationship without addressing the underlying skeletal problem and may consume anchorage and posterior space unnecessarily.

Age and dental development are particularly important. The period before eruption of the second permanent molar is advantageous but also should be cautions because early distalization impacts posterior growth and the developing third-molar region can influence available space. Headgear treatment showed greater initial distalization before second-molar eruption, with a slower rate after eruption. [39] Similarly, studies of Pendulum appliances in the mixed dentition demonstrated that the quality of deciduous-molar anchorage can vary with root resorption and dental developmental stage [22].

Distalization is most predictable when there is a mild-to-moderate dental Class II discrepancy, a favorable or controllable vertical pattern, sufficient posterior space, a facial profile that benefits from space creation rather than further anterior protrusion, and a clear biomechanical endpoint. Where these conditions are absent, alternative strategies—including extraction, growth modification, total-arch skeletal anchorage, or surgical correction—should be considered according to the diagnosis.

Classification of molar distalization systems-

Molar distalizers are classified into extraoral and intraoral systems. Extraoral appliances include cervical-pull and combination headgear. Intraoral systems may be removable or fixed; fixed systems are broadly categorized as buccally acting or palatally acting. A second useful classification is based on the intended tooth movement—tipping versus bodily movement—and on whether movement occurs within one arch or between arches. [1]

Buccally acting systems include superelastic nickel-titanium mechanics, nickel-titanium coil springs, Jones Jig, Wilson's rapid molar distalization, K-loop distalizers, magnets, First Class and related systems. Their practical advantages include relatively straightforward placement and reactivation. Palatally acting systems include the Distal Jet, Nance-based systems, intraoral bodily distalizers, Pendulum and Piston-type appliances. The source document highlights the biomechanical advantage of palatal force application: the line of action may be positioned closer to the molar center of resistance, potentially improving bodily control and reducing tipping. [1]

Modern classification should additionally recognize skeletal anchorage as a distinct anchorage category rather than merely another appliance. Mini-screws may be placed buccally, palatally or in extra-alveolar sites, while miniplates can provide a more rigid skeletal anchorage source. These systems may support direct molar distalization, distalization of a posterior segment or total-arch distalization. The distinction is clinically important because the same distalizing spring can generate very different dental effects depending on whether the reaction force is absorbed by premolars and incisors or by bone.

Biomechanical principles-

The central biomechanical challenge in distalization is to generate a distal force while controlling the accompanying moment. The position of the line of action relative to the molar center of resistance determines whether the tooth tends toward distal crown tipping, bodily translation or a combination of crown and root movement. The supplied review notes that the center of resistance is approximately in the mid-root region; a force vector below this region favors distal crown tipping, a vector through the center of resistance favors translation, and a vector positioned more apically can promote greater root movement. [1]

Moment-to-force ratio is therefore a key design variable. A distalizing force applied far from the center of resistance generates a larger moment and greater tipping. In contrast, force application closer to the center of resistance can improve translatory control. This principle explains why palatal and skeletal-anchorage systems designed with appropriate vertical force arms can produce more controlled movement than appliances whose force is applied primarily at the crown level. However, a more favorable line of action does not eliminate biological limitations, root proximity, cortical resistance or appliance deformation.

Friction and mechanical resistance can also modify the effective force. The biomechanical simulations summarized in the source document reported substantial frictional losses during coil-spring distalization, with losses increasing in some arch-guided configurations.

These findings support the use of controlled, physiologically appropriate forces rather than assuming that the nominal activation of a spring is equivalent to the force delivered to the tooth. [6,7]

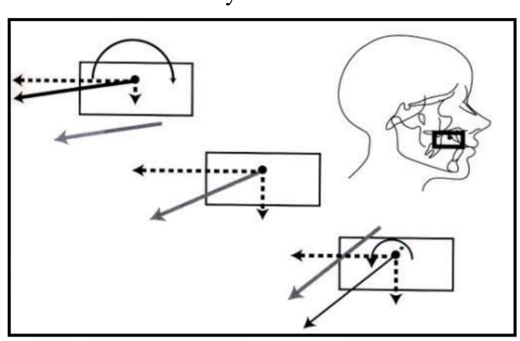
Anchorage is the second major determinant of treatment quality. In conventional intraoral distalization, Newton's third law means that the distal force applied to the molar produces an equal reaction on the anchorage unit. The clinical manifestation may include mesial migration or proclination of premolars and incisors, increased overjet, bite opening or occlusal-plane changes. In skeletal anchorage, the reaction force is transferred to bone, reducing—but not necessarily eliminating—reciprocal dental movement. The evidence summarized in the review consistently indicates that anchorage design is at least as important as the distalizing spring itself. [23–40]

Extraoral distalization: headgear-

Headgear remains a biomechanically versatile distalizing system because its anchorage is external and its force direction can be modified. Cervical-pull headgear delivers a distal and extrusive component and may influence the occlusal plane and vertical dimension. Occipital or high-pull systems provide a more superior vector and can introduce an intrusive component. Combination-pull systems permit further customization of the resultant vector. [1]

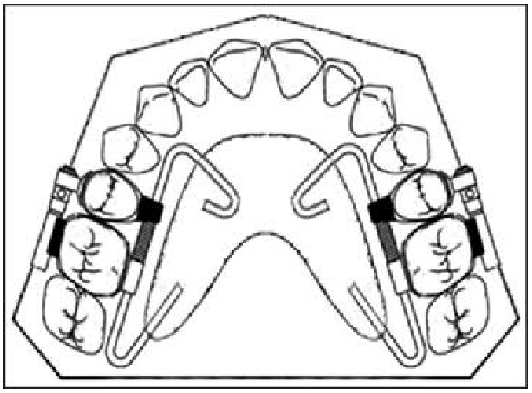
Clinical evidence summarized in the source document demonstrates that headgear can produce distal molar movement and can influence maxillary growth and vertical development in growing patients. Nevertheless, the effectiveness of treatment is sensitive to compliance. A recent randomized trial cited in the document specifically examined the role of compliance in headgear outcomes, reinforcing the continuing clinical relevance of this limitation [2]. Comparative work has also shown that intraoral distalizers can achieve molar correction more rapidly than extraoral traction, although at the cost of greater anchorage effects. [8,20]

Headgear is therefore not obsolete; rather, its role is selective. It remains valuable when control of force direction, vertical effects or maxillary growth modification is desired and when adequate compliance can be expected. Its limitation is not mechanical inefficiency but the dependence of the intended force system on actual wear. For patients unwilling or unable to wear headgear consistently, non-compliance and skeletal-anchorage alternatives may offer more predictable force delivery.

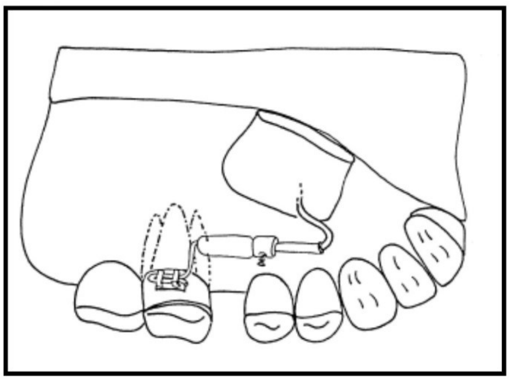


Headgear: extraoral force system.

Carriere molar distalisation

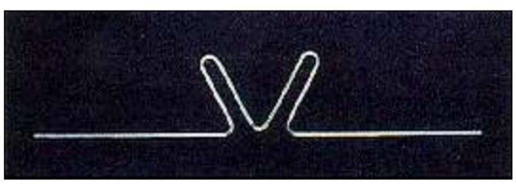


First-Class appliance.



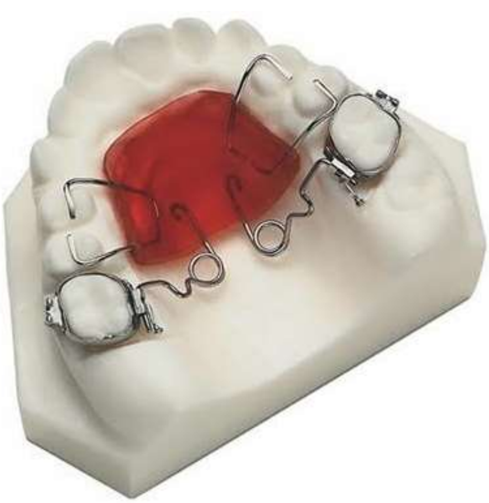
Distal Jet Appliance

Distal Jet appliance.



K - Loop

K-loop distalizer.



Pendulum appliance.

Jones Jig: intraoral distalization system.

Conventional intraoral distalizers-

7.1 Pendulum and Pend-X- The Pendulum became one of the most widely discussed non-compliance distalizers because it can generate substantial distal molar movement without patient cooperation. In a large clinical series, approximately 5.7 mm of first-molar distalization was accompanied by about 10.6 degrees of distal tipping and mesial movement of the anterior anchorage unit. [9] Other studies reported distalization of approximately 4.6 mm with greater tipping in some protocols. [21] The Pendulum is therefore effective, but its side effects must be actively controlled with uprighting mechanics, modified spring geometry, staged activation or skeletal anchorage.

7.2 Jones Jig- The Jones Jig was introduced as a non-compliance intraoral appliance for rapid Class II molar correction. In the study summarized in the source document, first-molar distalization averaged 2.51 mm with approximately 7.5 degrees of distal tipping, while premolars moved mesially. These findings illustrate a recurring theme: successful correction of the molar relationship does not necessarily mean that the entire measured space represents true posterior translation. [11]

7.3 Nickel-titanium coils and magnets- Early intraoral systems used repelling magnets and superelastic nickel-titanium springs. Comparative studies summarized in the source document generally favored nickel-titanium coils for movement achieved, while magnets were associated with greater tipping in some comparisons. [4,5,12] Their main advantage is continuous force delivery without the need for external appliances. Their principal limitation is reciprocal anchorage loss when the anchorage unit is dental.

7.4 Distal Jet- The Distal Jet uses a palatal Nance-based anchorage system and a piston-spring mechanism. 3.2 mm first-molar distalization with relatively modest distal tipping, but also measurable premolar anchorage loss. [14] Subsequent modifications were developed to improve activation, conversion to retention and mechanical reliability. Its clinical value lies in controlled palatal force application and the possibility of converting the active appliance into a passive retainer after distalization.

7.5 K-loop and First-Class systems. The K-loop and First-Class appliances were developed to improve control and reduce dependence on patient cooperation. A randomized trial of the First-Class appliance demonstrated significant distalization compared with untreated controls, while recognizing distal tipping and anterior anchorage loss. [30] **Carriere molar distalisation** is new method of distalization using elastics. These systems remain useful when their biomechanical characteristics match the patient's vertical and sagittal requirements.

Skeletal anchorage and the modern paradigm-

The most important recent change in molar distalization is the incorporation of temporary skeletal anchorage devices. Mini-screws and miniplates permit the reaction force to be transferred to bone rather than primarily to the anterior dentition. This can reduce incisor proclination, premolar mesialization and unwanted occlusal-plane changes, while permitting distalization in adults who may have limited growth potential. [27,33,34]

Bone-anchored Pendulum systems demonstrated that substantial distalization could be obtained without the anterior anchorage loss characteristic of conventional Pendulum appliances. The source document reports approximately 6.4 mm of first-molar distalization in one study, although distal tipping remained evident. [23] Comparative work between conventional and bone-anchored Pendulum designs showed that skeletal anchorage reduced anchorage loss and permitted more controlled posterior movement. [26] Thus, skeletal anchorage should not be interpreted as automatically producing bodily movement; force-vector design remains essential.

Mini-screw-supported distalization systems have progressively evolved toward translatory movement and total-arch distalization. The source includes evidence for skeletonized Distal Jet systems, mini-screw-supported Pendulum appliances, iPANDA, interradicular mini-screw configurations and palatal plates. [28,34,36,38] In a comparison of implant-supported systems, the mini-screw implant-supported distalization system produced nearly bodily distalization, whereas the bone-anchored Pendulum produced more distal tipping [33]. This finding emphasizes that anchorage location and appliance geometry, rather than the presence of a mini-screw alone, determine movement quality.

Palatal skeletal anchorage appears particularly promising. Finite-element work summarized in the review found that buccal mini-screw configurations could produce distal tipping and extrusion, whereas a palatal plate favored bodily molar movement with minimal incisor displacement. [38] More recent finite-element analyses similarly reported greater distal molar displacement and reduced premolar mesial movement with direct palatal anchorage [53]. Clinical studies have also demonstrated that palatal skeletal anchorage can provide meaningful distalization with relatively small changes in molar inclination and vertical dimension. [43,50]

The emerging principle is therefore “anchorage by design.” A mini-screw should not be selected simply because it provides compliance-free mechanics. Its position, number, height of force application, relationship to the center of resistance, soft-tissue environment, root proximity and intended sequence of posterior movement should all be considered before activation.

Sequential versus en-mass distalization-

The presence and eruption status of the second molar strongly influence distalization mechanics. When only the first molar is erupted, distalization can be relatively efficient. Once the second molar is erupted, the clinician must move a larger posterior unit or accept a sequential strategy. Distalization before second-molar eruption is faster, while movement remains possible after eruption at a slower rate. [39]

Sequential distalization attempts to move the first molar first, followed by the second molar and then the premolars/anterior segment. This can reduce the instantaneous resistance of the posterior unit and may permit more controlled movement, but it lengthens the number of active phases. Simultaneous distalization may shorten the sequence but demands greater anchorage and force control. Comparison of segmented and quad-Pendulum approaches showed both to be effective, with the simultaneous approach associated with greater molar extrusion and vertical dimensional change. [37]

For skeletal-anchorage-supported systems, the decision may be individualized. If sufficient posterior space exists and the force vector is appropriately controlled, en-masse distalization of the posterior dentition or entire arch may be feasible. In other cases, sequential movement may avoid root interference and maintain a more favorable force system. Three-dimensional imaging and digital setup can assist in determining whether the planned distal movement is anatomically realistic.

Clinical effects and unwanted consequences-

Molar distalization should be evaluated as a three-dimensional tooth movement, not merely as a change in molar relationship. The most frequently reported dental effects in the supplied literature are distal crown tipping, molar rotation, extrusion or intrusion, premolar mesialization, incisor proclination or retrusion, overjet change and alterations in overbite. The magnitude of these effects varies substantially among appliances and anchorage configurations. [9–16,21,31]

Vertical control is particularly important in high-angle patients. Conventional Pendulum and cervical headgear mechanics may introduce extrusion or bite opening, whereas palatal skeletal anchorage can be designed to deliver an intrusive component when required. Increase in FMA and reductions in overbite in studies using conventional distalizers. [41] Conversely, some skeletal anchorage systems have produced molar intrusion and mandibular plane reduction depending on the force-vector position. [36]

Transverse and rotational effects also require attention. Posterior teeth do not necessarily move in a purely sagittal direction. The Pendulum may generate transverse expansion and rotation, while unilateral distalization can affect the contralateral anchorage unit. The clinician should therefore monitor molar rotation, arch width, occlusal-plane cant and midline position rather than relying solely on sagittal molar measurements. [21,24]

Soft-tissue changes are generally secondary to the dentoalveolar movement rather than direct skeletal effects. In patients with a favorable profile and maxillary dentoalveolar protrusion, distalization may facilitate anterior retraction and reduce lip prominence. Skeletal-anchorage-based distalization can improve anterior retraction and reduce unwanted molar mesialization in selected adult patients. [27] However, distalization should never be used simply to avoid extraction when the resulting posterior movement would be excessive or biologically unfavorable.

Long-term stability and retention-

Long-term stability is an essential but relatively underrepresented outcome in the literature summarized in the source. Tooth movement produced by distalization is followed by remodeling and adaptation of the periodontal tissues, and molar inclination may change after active treatment. A five-year evaluation cited in the review found that maxillary first-molar angulation after Pendulum-based treatment changed over time, with roots tending to upright toward their pretreatment position. [42] This finding highlights the distinction between maintaining a molar relationship and maintaining the exact post-treatment tooth inclination.

More encouraging long-term data are available for mini-screw-anchored distalization. A study cited in the review followed a distalization group and controls for approximately 3–4 years and found that the distalized molars remained relatively stable, with subsequent mesial movement comparable to controls. [46] This suggests that improved biomechanical control during active distalization may contribute to favorable long-term stability, although retention remains necessary.

Retention should be integrated into the treatment plan from the beginning. Once the desired molar position has been achieved, the active distalizer should be converted to a stabilizing mechanism or replaced by an appropriate fixed/removable retainer. The period immediately following distalization is particularly important because the molars and adjacent tissues are adapting to a new position. Finishing mechanics should also upright roots and establish stable intercuspation before the appliance is removed.

Clinical decision-making: choosing the right distalizer-

Appliance selection should be individualized according to five major domains: diagnosis, dental development, vertical pattern, anchorage requirement and desired movement. A practical decision pathway is presented in Table 1.

For a growing patient with a mild dental Class II relationship and adequate compliance, headgear may remain a powerful option when vertical and skeletal effects are desired. For a patient requiring non-compliance mechanics but accepting some reciprocal anchorage effects, a conventional Pendulum or Distal Jet may be appropriate. For an adult or a patient in whom incisor position must remain stable, skeletal anchorage becomes increasingly attractive. When bodily movement or total-arch distalization is required, a palatal mini-screw/plate-supported system may provide a more favorable force system than a conventional dental-anchored distalizer. [27,33,38,43,50,53]

The clinician should also determine whether the goal is molar correction alone or complete arch distalization. If the anterior teeth are already well positioned and only the molar relationship is incorrect, a localized distalizer may be sufficient. If there is generalized maxillary dentoalveolar protrusion, a total-arch skeletal anchorage strategy may be more efficient. If the discrepancy is primarily skeletal, distalization alone may provide an incomplete correction and should not be selected simply because it is non-extraction.

Clinical synthesis-

The clinician should regard molar distalization as a biomechanical strategy rather than a specific appliance. The objective is to move the posterior dentition distally while preserving the position of structures that should remain stable. Every distalizing system creates a force-reaction system. The quality of treatment is determined by where that reaction is expressed and whether the resulting tooth movement matches the intended treatment plan.

Three principles emerge from the literature reviewed. First, distalization is most predictable in carefully selected dentoalveolar Class II cases with adequate posterior space and a favorable vertical pattern. Second, conventional non-compliance appliances are effective but commonly produce some combination of distal tipping and anchorage loss; these effects must be anticipated rather than considered unexpected complications. Third, skeletal anchorage provides a major opportunity to improve anchorage control, but its benefits are maximized only when the mini-screw/plate location and force vector are deliberately selected to approximate the desired center-of-resistance mechanics. [23,26–28,33,38,43,50,53]

In practical terms, the most important clinical question is not “How many millimeters can this appliance distalize a molar?” but “How much of the desired space can be generated by controlled posterior translation without compromising vertical, transverse, periodontal or anterior tooth position?” This shift in thinking is particularly relevant in adult orthodontics and in patients for whom incisor position and facial aesthetics are critical.

Conclusion-

Molar distalization has progressed from extraoral headgear to sophisticated intraoral and skeletal-anchorage-supported systems and remains an important component of contemporary non-extraction orthodontics. The evidence reviewed demonstrates that a wide range of appliances can establish a Class I molar relationship and create clinically useful space, but the nature of the movement differs substantially among systems. Conventional appliances may be efficient but are frequently associated with distal tipping, premolar mesialization, incisor proclination and vertical effects. Skeletal anchorage reduces the dependence on dental anchorage and can facilitate more controlled posterior or total-arch movement, particularly when palatal anchorage and favorable force vectors are used.

No single distalizer can be regarded as ideal for all patients. Age, growth pattern, second-molar eruption, sagittal discrepancy, vertical dimension, available posterior space, periodontal anatomy, anchorage requirements and the desired type of tooth movement should determine appliance selection. Long-term stability also depends on root control, finishing and retention rather than on the distalization appliance alone. Future well-designed prospective studies using standardized three-dimensional outcomes and long-term follow-up are needed to determine the relative effectiveness, efficiency and stability of contemporary distalization systems.

Table 1. Practical clinical selection framework for maxillary molar distalization

Clinical situation	Preferred strategy	Main rationale	Main caution
Mild dental Class II; growing patient; good compliance	Headgear or selected intraoral distalizer	Direct control of distal force; growth can assist correction	Compliance and vertical effects
Mild–moderate dental Class II; non-compliance required	Pendulum / Distal Jet / K-loop / First Class	No routine external wear; clinically established	Tipping and reciprocal anchorage loss
Adult Class II with stable incisors required	Mini-screw-supported distalization	Anchorage independent of anterior dentition	Root proximity, soft tissue and mini-screw stability
Need for bodily molar movement	Palatal skeletal anchorage with controlled force vector	Force can be positioned closer to center of resistance	Requires careful three-dimensional planning
Generalized maxillary dentoalveolar protrusion	Total-arch distalization using skeletal anchorage	Can distalize posterior and anterior segments with minimal reciprocal movement	
High-angle / open-bite tendency	Intrusive or vertically controlled skeletal anchorage	Allows force-vector control and potential molar intrusion	Avoid uncontrolled extrusion
Second molars erupted	Sequential or carefully planned en-masse distalization	Accounts for increased posterior resistance	Slower movement and greater anchorage demand
Unilateral Class II subdivision	Asymmetric distalization; skeletal or controlled intraoral anchorage	Targets only the affected side	Occlusal-plane cant and contralateral effects

Table 2. Treatment effects reported in the literature

Modality / study	Sample or design	Reported distalization	Important associated effect
Pendulum; Bussick & McNamara	101 patients	≈5.7 mm first molar	≈10.6° distal tipping; anterior anchorage movement
Intraoral bodily molar distalizer; Keles	15 patients	≈5.23 mm	Minimal molar tipping/extrusion; premolar/incisor anchorage effects
Jones Jig; Brickman et al.	72 treated; 35 comparison	≈2.51 mm	≈7.53° distal tipping; premolar mesial movement
Distal Jet; Bolla et al.	20 growing subjects	≈3.2 mm	≈3.1° distal tipping; premolar anchorage loss
Bone-anchored Pendulum; Kircelli et al.	10 patients	≈6.4 mm	≈10.9° distal tipping; little anterior movement
MISDS vs BAPA; Sar et al.	14 + 14 patients	Successful posterior distalization	MISDS near-bodily movement; BAPA more tipping

Modality / study	Sample or design	Reported distalization	Important associated effect
iPANDA; Suzuki et al.	20 adults	≈4.5 mm	≈1 mm intrusion; no significant inclination change
MCPP vs headgear; Park et al.	44 adults	MCPP ≈4.2 mm crown / 3.5 mm root	≈3.9° tipping and ≈2.5 mm intrusion; headgear more tipping
Mini-screw-supported distalization; Bechtold et al.	19 distalization + 19 controls	≈4.2 mm first molar	Minimal crown tipping; stable at 3–4 years
Direct palatal mini-screw FEA; Guo et al.	3-D finite-element models	Greatest molar displacement among tested anchorage designs	Reduced premolar mesial movement and lower stress in selected structures

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