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Biomechanics in orthodontics: A review

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Abstract
In the execution of an orthodontics treatment plan, levelling and alignment is the most important part. This is usually achieved by placing brackets on the malaligned teeth, which are of increasing thickness. Adequate and favourable tooth movement may or may not result by the force generated on insertion of straight wires into brackets of such teeth, which depends on geometric relationship and also the expected outcome. Whether an applied force system with the use of straight wire is beneficial is determined by analyzing the relationship between adjacent teeth. When the side effects of the insertion of straight wire are unwanted, alternate treatment plans like use of inter arch, extra oral, or auxillary appliances is indicated. With proper treatment planning and evaluation of the force systems generated, any unplanned tooth movement can be avoided and overall treatment efficiency can be improved.

Keywords: alignment, levelling, deep overbite, open bite, intrusion

Introduction

Levelling with Straight Wires [1].

L F Andrews introduced the technique of levelling and alignment by straight wire in the 1970s and it became a popular technique. Reduction at chair side time and simplicity of use made this technique popular. However, the straight wire technique remains unsuitable for the treatment of all malocclusions. Asymmetric buccal occlusion and unilateral vertical discrepancies are amongst certain types of malocclusions that may not be easy to treat with the use of straight wire. However, there is a systematic approach for analyzing these clinical solutions. Burstone and Koenig developed wire positioning between 2 brackets and also analyzed the force system. The bracket positioning was done in such a manner that one brackets, angulation was increased and one was allowed to remain stationary. A ratio of the angulation between the two brackets was calculated and wired among -0.5,-0.75,-1.0,0,0.5 and 1.0 respectively. The force system generated by each of the six V geometries was described. Analysis of all the different geometries was done.3 geometries, namely I, IV, VI are of special significance. Figure 1. Bracket geometries I, IV and VI with their respective force systems.

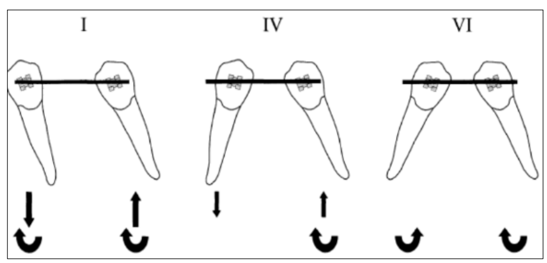

Fig 1

Side effects of straight wire mechanics in the first order [2]

To counter effects of straight wire mechanics in the 1st order, a simpler approach needs to be adopted for analysis of the force system acting on the entire arch, as the complexity involved makes the analysis difficult. Therefore two segments can be isolated and beginning at the midline, the relative relationship of each pair of teeth can be observed.

A corresponding force system is drawn out after evaluation of geometric relationship between these teeth, beginning at the two central incisors. Using a similar approach, relationship between lateral and central incisors is studied. All moments and forces acting within the arch are measured and identified, and a final force diagram is prepared. In the mandibular arch, the geometric relationships of all teeth present a good illustration for determining if the straight wire method is appropriate or not. The two central incisors are rotated mesially and create a V geometry which is symmetrical. As illustrated in fig3.B, the expected corrective force systems should involve two equal and opposite moments. Emplacement of a straight wire into the wire brackets of all teeth in the involved arch results in correction of the malocclusion present, which is illustrated in fig 2. The force system is called consistent in this situation.

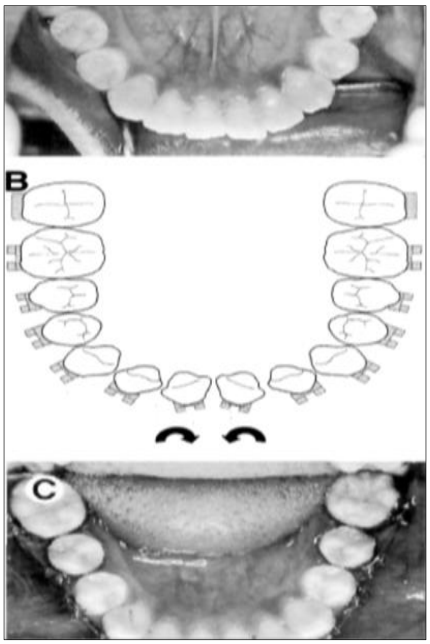

Fig 2: shows mandibular arch with two central incisors rotated mesially inward in an occlusal view.

a. Shows system generated after placement of straight wire into brackets of 4 anterior teeth.
b. Occlusal view showing corrected malocclusion
c. A systemic v geometry is not the only consistent geometry for use of straight wire.

(Fig 3.A) Illustrates a series of step geometries. The force systems involves moments on the incisors as well as labio lingual forces their alignment. The force system developed by counter clock wise moments on the two central incisors as well as lingual moment of the left central incisors and labial moment of the right central incisor will be created by the force system developed by placing a straight wire into the brackets of 4 anterior teeth (fig. 3, B). Fig. 3, C illustrates the initial alignment of the teeth with a straight wire. More often, the initial geometry is not benificial for alignment using straight wire.

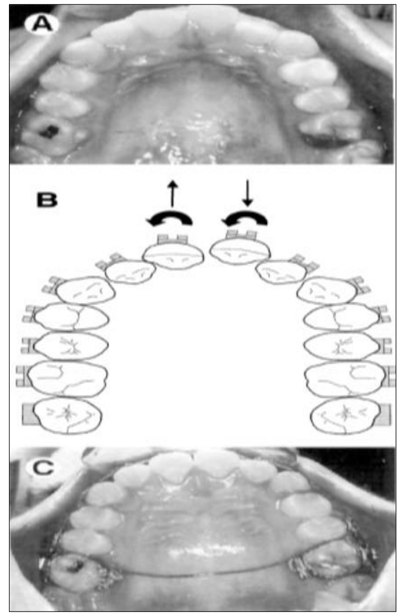

Fig 3

Fig 3: malocclusion with a series of step geometries seen in occlusal view (A). The force system on the two central incisors (B). Clinical view of the corrected malocclusion using a straight wire approach (C).The mandibular malocclusion shown in (Fig. 3, A) shows a lingually positioned right lateral incisor. In this case the geometric relationship between the right lateral and central incisor is a step geometry and the insertion of a straight wire into the brackets of the four anterior teeth will align the teeth and also create a midline to the right side (fig. 3,B and 3,C).

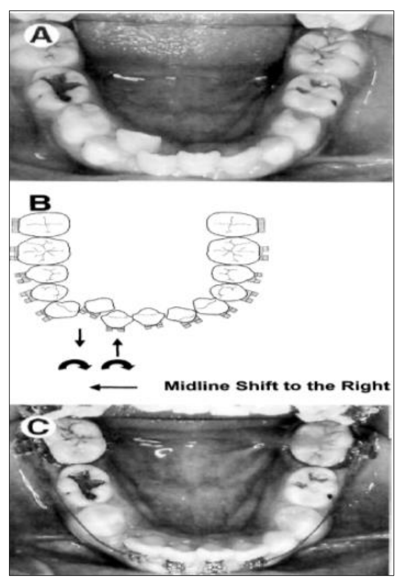

Fig 4

Fig 4: Depicts occlusal view of a malocclusion with a lingually positioned mandibular right lateral incisor (A). The force system generated by insertion of a straight wire (B). Occlusal view of the corrected malocclusion (C).Rotated teeth may also show geometries that will not be consistent with the positioning of a straight wire for their alignment. The relationship between the central incisors is a step geometry and an asymmetric V geometry is seen between the central and lateral incisors on the right side, as shown in the maxillary arch in (fig 5.a) Force system Analysis indicates that, although correction of two central incisors will occur as a result of straight wire placement, the right lateral incisor is displaced labially, which is an unwanted side effect (Fig. 5,B). Fig. 6, C illustrates the clinical results of straight wire placement into the mal-aligned teeth with labial moment of the right lateral incisor. Apparently sometimes it is beneficial to not insert a straight wire into all the teeth in an arch. By passing the teeth that may experience undesirable side effect is suggested in select situations after careful analysis of the force system that would be generated by engaging an arch wire. The force system generated by a straight wire may, in some cases, worsen the initial malocclusion.

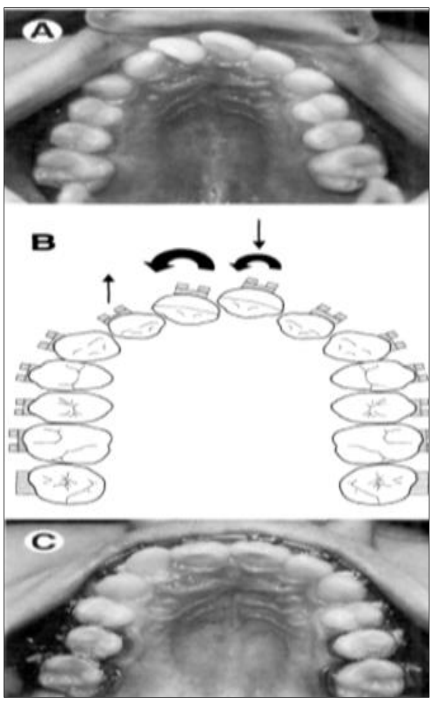

Fig 5

Fig. 5: Occlusal view of a malocclusion with a step geometry (A). Insertion of a straight wire results in generation of an inconsistent force system (B). Placement of a straight wire resulted in undesirable side effects of the right lateral incisor (C).The maxillary arch shown in (Fig. 6) shows a palataly placed, small, right lateral incisor, which is rotated distally inward, the left central and lateral incisors, and the relationship between them. The relationship between the right lateral and central incisors is identified as an asymmetric V Geometry. Analysis of the force system indicates that, although the left lateral incisors will be corrected by mesial rotation and labial movement, the right lateral incisor will further move lingually (Fig. 6, B). It is therefore appropriate to bypass the right lateral incisor initially and tie the wire only into this tooth leaving the rest of the arch in better alignment. The arch can then be joined together to provide enough anchorage for correction of the right lateral incisor position without any undesirable side effects (Fig. 6, C).

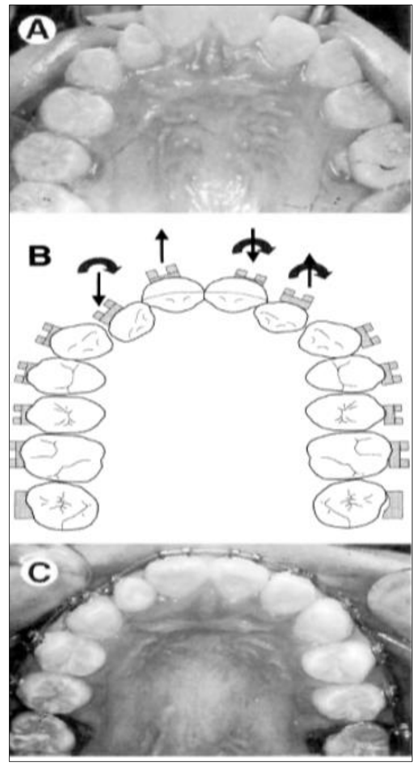

Fig 6

Fig. 6: Occlusal view of a malocclusion with a combination rotations of the incisors and step geometries (A). The force system generated by insertion of a straight wire indicates that the lingual position of the right lateral incisor gets worsened (B). The correction achieved for the central incisors and the left lateral incisor (C). Adequate anchorage for correcting the right lateral incisor position without undesirable side effects. Posterior teeth may also be mal-positioned and may also require alignment. Mesially rotated first molars are common discrepancies that often require correction in the initial phase of treatment of a class II malocclusion. Malocclusion present when a straight wire is inserted into brackets of rotated molars, the relationship between the brackets of the premolars and the buccal attachment of the molar presents an asymmetric V Geometry. The rotated molars will be rectified as a result of the moment created. Expansion of the molar region will also occur as well as narrowing of the premolar region as a result of the transverse force developed between the molars and premolars (Fig. 7). It is therefore, beneficial to isolate the molars bilaterally and correct their rotations without connecting them to the rest of the arch.

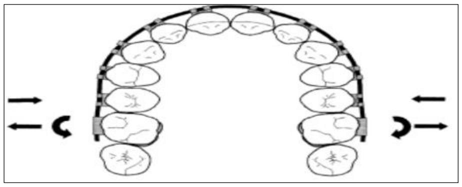

Fig 7

Fig. 7: Shows Force system generated when a straight wire is inserted into bilaterally mesially inward rotated maxillary first molars. Expansion of the molar region is anticipated, as well as constriction in the premolar areas. Use of transpalatal arch fabricated of 0.030 inch stainless steel or a precision palatal arch prefabricated of 0.032 x 0.032 inch titanium molybdenum alloy (TMA) permits correction of the rotated molars without any unfavourable effect on the rest of the dental arch (Fig. 8).

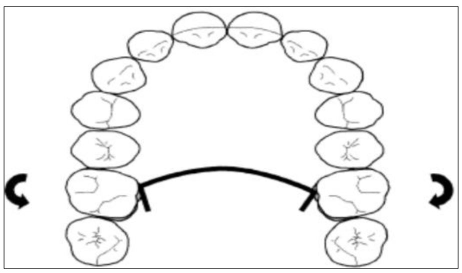

Fig 8

Fig. 8: The force system generated by a palatal arch is the one desired to correct bilaterally mesially inward rotated maxillary first molars.

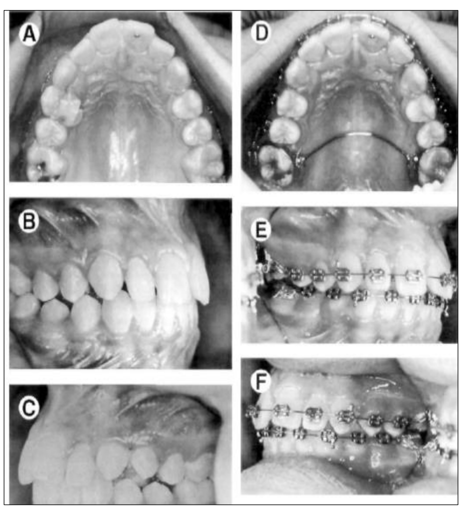

Fig 9

Fig. 9: Shows occlusal view of a maxillary dental arch showing rotated first molars bilaterally (A). The right (B) and left (C) buccal relationships are vaguely in Class II relation. The occlusal view (D) shows the aligned arch, and also the right (E) and left (F) buccal relationships have improved. (Fig. 9, A), depicts a maxillary arch with bilateral mesial inward rotations of the first molars in a patient with a mild class II dental relationship (Fig. 9, B and 9, C).Using a segment of straight wire, The maxillary anterior teeth were aligned. Correction of the molar rotations bilaterally was done using a palatal arch as shown in figure. The class 2 relationship of the molars enhanced as a result of the mesial out rotations shown in fig 9 E and 9 F It is critical to control molar width and rotations during space closure. Commonly premolars and/or canine will rotate distally inwards as they are retracted and molars will rotate mesially inward as they experience a mesial force during space closure. These after effects cannot be efficiently controlled in a straight wire system and also the clinician usually relies on the renewal of initial, light wires with continuously massive wires for the side effects to work themselves out eventually. Installments of bends or curvature in the arch wire to control these side effects has also been recommended. Using sliding mechanics, additional frictional force is likely to be introduced by adding bends or curves in treatment modalities and it may result in lengthening of the overall treatment time. To control molar rotation efficiently, transpalatal arch can be used. To provide enough rigidity to prevent unwanted molar rotation or width changes by using stainless steel 0.032*0.032 inch square wire or 0.034 inch round transpalatal arch. Occlusal view of the maxillary arch

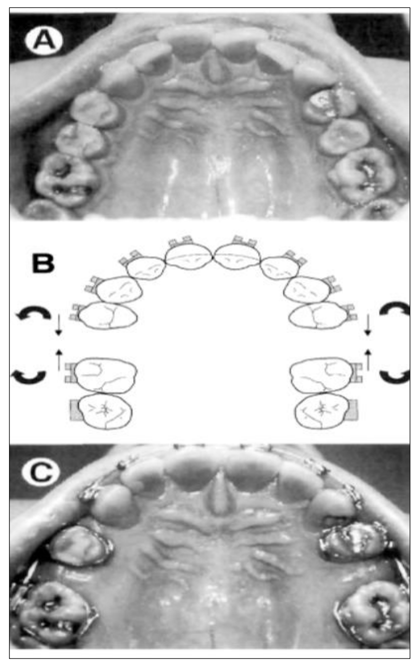

Fig 10

(As shown in fig 10). Before extraction of the second premolars (A). Diagrammatic representation of the force system generated during space closure (B). Clinical side effects(C).

Side effects of straight wire mechanics in 2nd order [3].

During orthodontic therapy, control of the occlusal plane is of specific importance. The common side effect is steepening of the occlusal plane when positioning a straight wire into the bracket of the distally tipped canine. Thw anterior segment of the teeth will extrude and the bite will deepen as the root of the canine is more distal. Another example is during extrusion of a highly placed canine unilaterally. (Fig. 11, A), shows the force system delivered by insertion the of a straight wire through a highly placed maxillary right canine. The canine will extrude as expected, but the lateral incisor and first premolar on that side will intrude.

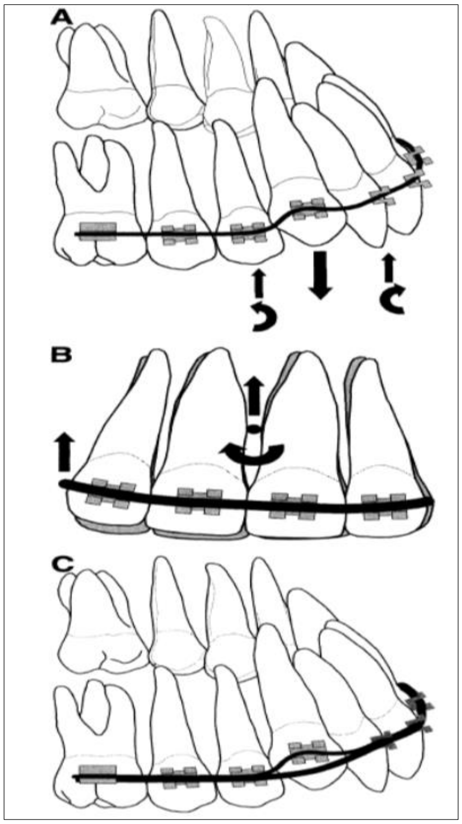

Fig 11

Fig. 11: Schematic representation of the force system resulting from insertion of a straight wire in a highly placed, and buccally oriented canine on the right side of the arch (A). Frontal view showing the development of a cant of the anterior occlusal plane (B). Schematic representation of a straight wire and a bypass arch wire used to erupt a canine simultaneously (C)Alternatively, it is possible to extrude a highly placed, buccally oriented canine using a cantilever arm that extends from an auxiliary tube on the molar (Fig.12). In this case, a heavy stainless steel arch wire is inserted that bypasses the canine. A passive palatal arch can be placed to connect the right and left buccal segments of teeth. This helps to establish an appropriate anchorage unit to avoid unfavourable effects as the canine is extruded. The intrusive force experienced by the posterior segment on that side is disturbed to several teeth, and therefore, its expression is minimized. Undesirable effects may also be seen clinically when canines present at different heights are aligned with a straight wire.

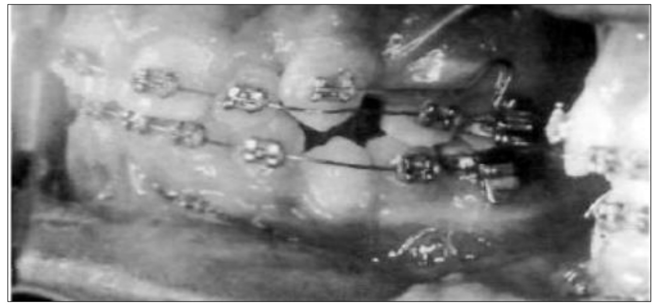

Fig 12

Fig. 12: Clinical example of a cantilever used to erupt a canine in the maxillary arch [4].

Fig. 13 shows the development of a cant of the anterior occlusal plane when a straight wire is inserted without prior analysis of the force system that will be generated in this case, use of cantilevers from the molar auxiliary tubes with an arch wire bypassing the canines would have been strongly suggested to avoid the side effect observed.

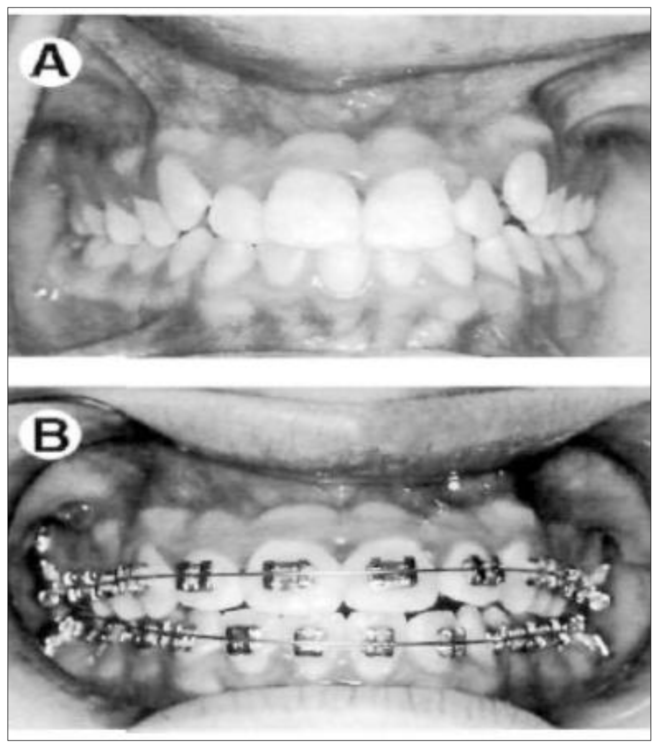

Fig 13

Fig. 13, A and 13, B Clinical example of a malocclusion with two canines at different vertical positions (A). Placement of a straight wire to correct this malocclusion results in the development of a cant of the anterior occlusal plane (B) and tip towards the canine space. An open bite may result on that side of the arch, and the anterior occlusal plane will be canted up on the right side (Fig. 11, B). Clinically, the cant of the anterior occlusal plane can be avoided by tying a rigid wire into the brackets of teeth in the arch and by passing the highly placed canine. A flexible auxiliary overlay wire of 0.014 - inch or 0.016 - inch nickel titanium can then be used to extrude the canine against the stabilized arch (Fig 11, C).

Class 2 Mechanics, Deep Overbite Correction [5]

Deep bite is defined as the amount and the percentage of overlap of lower incisors by the upper incisors. The clinical crown height of one of the mandibular incisors may be calculated as the overbite. Fleming showed that between the ages of 9-12, overbite usually is increasing whereas in the period between age 12 and adulthood it is decreasing. The amount of deep bite is not always associated with a particular growth pattern. Teeth tend to erupt until there is a spontaneous eruption which is distributed by an interfering factor. For example thumb sucking or tongue interposition may prevent eruption of teeth until they reach the occlusal plane. Lower incisors may erupt until they reach the palatal vault in severe cases of class 2 div 1. If an antagonist is missing, further eruption of a tooth may occur, leading to occlusal interferences during normal jaw movements, which may cause TMJ complaints. Patients that show long faces or a class II point A to point B relationship require the vertical dimension to be controlled, with no rotation of the mandible downward and backward during the correction of the overbite. Intrusion mechanics of the incisors is required in these patients. On the other hand, there are patients with smaller vertical dimensions or individuals showing sufficient vertical growth potential for which the treatment of choice is the extrusion of posterior teeth. The decision to intrude or extrude is based on at least three factors: Skeletal convexity, vertical dimension and the inter-occlusal (freeway) space.

Incisor Intrusion [6]

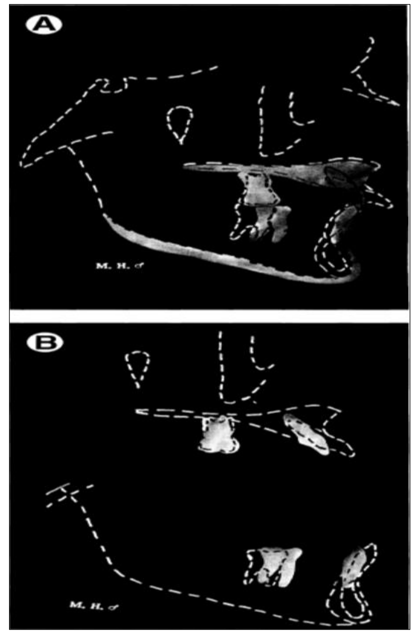

Fig 14

Fig. 14) shows a patient in whom intrusion was accomplished in both the upper and lower arches using light constant forces. Commonly, to maintain original cant of occlusion, upper incisors must be intruded more than the lower incisors. This requires controlled mechanics because in the class II patient, the application of class II elastics or cervical headgear and other similar mechanisms can steepen the plane of occlusion and negate any intrusion effects.

Fig. 14: Maxillary and mandibular intrusion using a continuous intrusion arch. Cranial base superimposition (A). Separate maxillary and mandibular superimpositions (B).

2 basic designs to intrusion arch are as follows [7]

A continuous arch, and A 3 piece intrusion mechanism. The application of each design is determined by the needs of the patient. The continuous intrusion arch is shown in (Fig. 15). A relatively rigid anchorage unit connects the teeth of the posterior segment. The cuspid is bypassed by placing a small step either in the region of the cuspid or eliminating the cuspid bracket entirely. Anterior teeth are connected together with an incisor segment. A 0.017 x 0.025 - inch or 0.016 x 0.022 - inch titanium molybdenum alloy (TMA) intrusion arch from an auxiliary tube places the intrusive force on the incisors. As the wire is brought down to the central incisors or the lateral incisors, only single forces are directed in an intrusive direction. The key to successful intrusion is control of the force system.

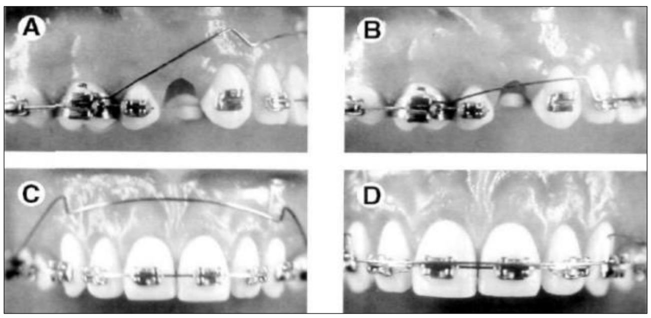

Fig 15

Fig. 15: Passive and active continuous intrusion arches. Separate posterior and anterior segments are placed. The canine is bypassed. Buccal view passive (A) and active (B). Frontal view passive (C) and active (D).Force magnitude can be determined either using tables or directly by a force gauge.

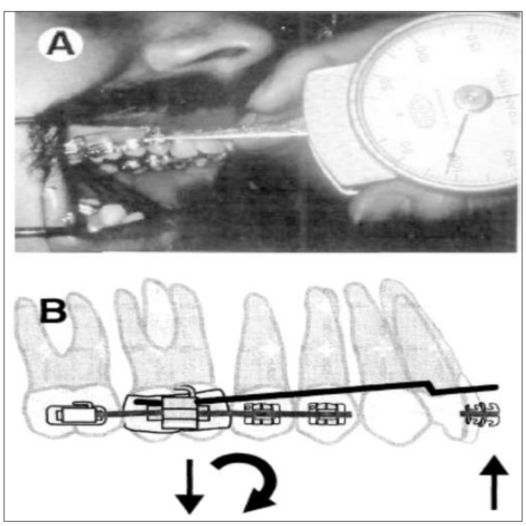

Fig 16

Fig. 16. Sometimes the clinician will neglect to measure the forces and only place a V bend posteriorly. This can be dangerous because arches vary in length and there is not a constant angulation for a desirable activation. If too much force is applied than required, unprecedented side effects, including steepening of the occlusal plane or distal tipping of a molar, can result. The magnitude of the force depends on the number of teeth and their size. For example, during intrusion of upper incisors, about 60 g of force for four incisors is used. Fig. 16: The force system. Measuring the force with a force gauge (A). The reactive force on the posterior anchorage unit produces potential extrusion and steepening of the occlusal plane.

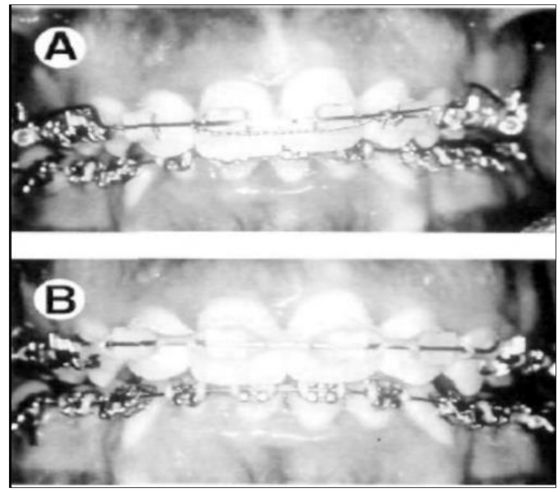

Fig 17

(Fig17) shows continuous intrusion arch before and after intrusion.

The use of low forces and a stable anchorage unit will not upset posterior anchorage and should maintain the original plane of occlusion. The force-deflection rate of the intrusion arch is very low, usually under 10 g/mm, because the distance between the auxiliary tube of the molar and the incisor Brackets is large. This not only produces a large deflection, minimizing the need for any reactivation, but also ensures greater constancy of force. It also enhances the accuracy of the appliance because any small error in activation produces a minimal change in the delivered force [8]. Fig. 17: Upper incisor intrusion. Before (A) and after (B). A particularly important consideration in intrusion is to ensure that the intrusion arch does not fit into the brackets of the incisors. Instead, separate segment is placed. Placement of either a rectangular or a round intrusion arch wire directly into an edgewise bracket anteriorly is desirable. The intrusive arch can change shape, producing displacement of the roots of incisors mesially.[9] Most importantly any torque, labial or lingual, can alter the intrusive force (Fig. 18). If purposely or accidentally placed lingual root torque is present, it could completely eliminate any intrusive force. At the other extreme, labial root torque may increase the intrusive force with a concomitant increase of extrusive force and tip back moment on the molar.

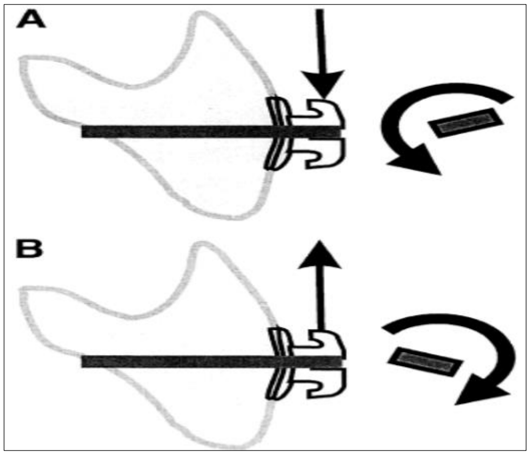

Fig 18

Fig. 18: Placing an arch wire in the incisor brackets changes the magnitude of the intrusive force.
Lingual root torque produces extrusion (A). Labial root torque produces intrusion (B).Once an edgewise intrusion arch wire is placed into the anterior brackets, a precise mechanism is not present. The clinician should carefully look at the anatomic arrangement of the teeth to determine which teeth require intrusion. Only the intrusion of two central incisors maybe needed in a Class 2 div 2 patient. Many Class II, Division I patients require intrusion of four incisors. These anatomic discrepancies should be eliminated by segmental intrusion rather than by indiscriminate levelling. If the patient initially has levelling wires placed in a full-arch wire, then it almost becomes impossible to produce effective intrusion of the incisors. One of the significant aspects of controlling the force generated during intrusion is to direct the force parallel to the long axis of the tooth [10].

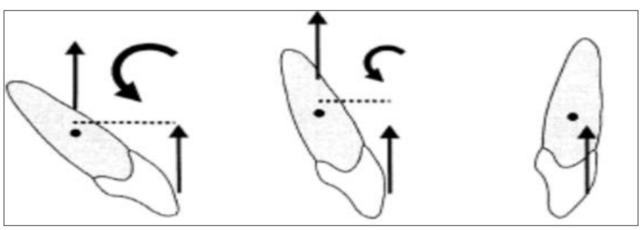

Fig 19

Fig.19: shows three different axial inclinations of incisors. A continuous intrusion arch can direct the force close to the center of resistance and parallel to the long axis of the tooth, with a vertical incisor. The incisor will readily intrude and will not retract or flare. The orientation of the tie is parallel to the direction of force [11]. By shortening the arm, the force can be directed more distally.12 Fig. 19: An intrusive force labial to the incisors produces different effects as axial inclinations vary. The intrusion force unfavourably moves the incisor root lingually in a flared incisor.

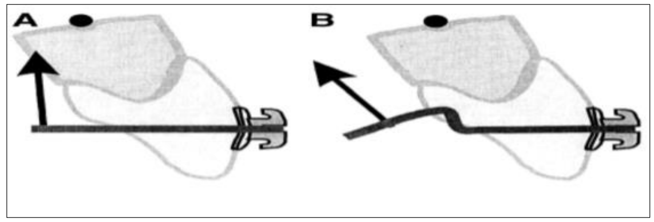

Fig 20

Fig.20: Angling of the posterior extension redirects the force parallel to the long axis of the incisor (A). Intrusive force on posterior extension of the anterior segment is at a right angle to the occlusal plane (B).The second method for redirecting the force is shown in (Fig. 20). A posterior extension to the anterior segment is angled so that the force is directed along the long axis of the teeth. This assumes that there is no friction along the arch wire so that the resulting force only acts at 90 degree to the posterior section of the anterior segment [12].
By using either a continuous intrusion arch or a 3-piece mechanism, the magnitude and the position of the force can be changed with respect to the center of resistance13 (Fig. 21).

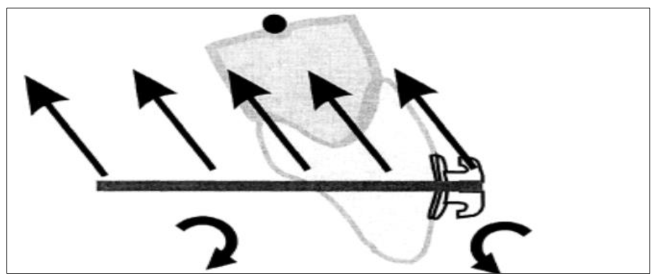

Fig 21

Fig. 21: Force can be positioned either posterior or anterior to the center of resistance of the incisor segment to produce intrusion-protrusion, pure intrusion, or intrusion-retraction.For optimal results, it is necessary to orient the force in such a way that it approaches parallelism to the long axis of the incisors. The use of a single force leads to an increased accuracy, than that achieved when an arch wire is positioned into the brackets of the incisors with a continuous arch or 2x4 mechanism. Key to anchorage control is the maintenance of low-magnitude force and the use of a rigid posterior segment. This includes a lingual or transpalatal arch to maintain posterior widths. Backup with occipital headgear may be considered. A posteriorly and intrusively directed force from the headgear that is acting anterior to the center of resistance of the molar segment produces a moment that lessens any steepening of the occlusal plane. Headgear should not be used to cover up errors in intrusion mechanics where force magnitudes are too great [24, 25].

Extrusion of posterior segments [13, 19-23]

The extrusion of posterior teeth for the correction of deep bite may be less demanding than intrusive mechanics but must still be accomplished carefully to avoid canting of the occlusal plane

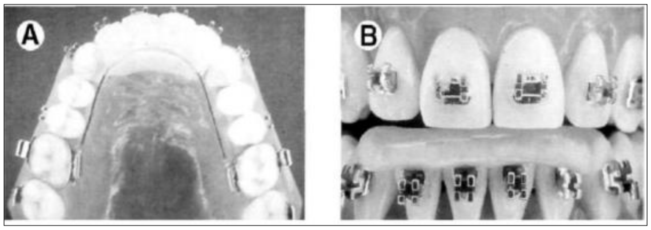

Fig 22

Fig. 22: Extrusive mechanics. Upper bite plate on precision lingual arch (A). Bite plate attached to the lower arch allows separated posterior teeth to be extruded with vertical elastics or allowed to erupt (B).

Many continuous arches cause extrusion of teeth. More efficiently, a 3-piece tip back mechanism with increased forces to a large anterior segment can be used to tip back and extrude the posterior teeth. To minimize any steepening of the upper plane of occlusion with larger forces, cervical headgear with a long and high outer bow can produce a movement to bring the upper plane of occlusion vertically without a change of cant. An upper bite plate attached to a precision lingual arch is a useful adjunct for posterior eruption with or without other mechanics (Fig. 22, A). Unlike removable bite plates, the fixed appliance is not under the control of the patient, which enhances its efficiency. A lower bite plate extending from cuspid to cuspid can also be used to separate the posterior teeth, allowing for vertical extrusive mechanics to be expressed more easily (Fig. 22, B). With posterior teeth separated by either an upper or a lower bite plate, vertical elastics can be used either on an entire segment or on individual teeth, because often not all teeth have to be erupted equally. The position of the force as well as the number of teeth in the buccal segment can be controlled [14-18].

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