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Review Article

Understanding bio-mechanics of intrusion: an orthodontics review

Disha Sharma[1], Gaurav Thakur[2], Deepak Gurung[3]*, Amrita Thakur[4]

[1]Department of Orthodontics, Regional Hospital, Bilaspur, Himachal Pradesh, India
[2]Department of Orthodontics, Hospital of Mental Health and Rehabilitation, Boileuganj, Shimla, Himachal Pradesh, India
[3]CMO Office, Bilaspur, Himachal Pradesh, India
[4]Department of Psychology, Sacred Heart Convent School, Dhalli, Shimla, Himachal Pradesh, India

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***Correspondence:**
Dr. Deepak Gurung,
E-mail: drdeepakgurung@yahoo.in

ABSTRACT

Orthodontic intrusion is a common treatment approach in managing orthodontic esthetic and functional problems, including gummy smile and deep bite. Intrusion often constitutes an integral part of orthodontic treatment to improve sagittal and vertical incisor relationships, to correct interincisal angle and, consequently, the gingival line and restore the esthetics of smiling. The choice of appliances and techniques used by practitioners varies radically among individuals, but the fundamental forces and moments they produce are universal. Appliances will always act according to the laws of physics. Therefore, understanding the basic biomechanical principles of intrusion may help in effecting efficient tooth control and help in achieving successful orthodontic treatment outcomes more predictable and consistent.

Keywords: Intrusion, Orthodontic treatment, Gingival line

INTRODUCTION

Orthodontics and dentofacial orthopedics encompass modification/alteration of the teeth and the supporting bones to attain desirable changes in their relative position so that esthetics, function, and oral health of the patient can be improved. A complete understanding of the aesthetic development of the face, the mechanics involved in growth modification and the tooth movement is important. Also, an appreciation of the biological mechanisms is critical.[1]

For a long time, orthodontic treatment was primarily based on occlusal relationship results.[2] Currently modern orthodontics also requires a harmonious balance between soft tissues and occlusion. The influence of smile attractiveness components is important because it allows the professional to identify the hierarchy of esthetic preference.[3] The value of a beautiful smile is undeniable as this is the first thing that is noticed about anybody. An attractive smile in modern day society is considered an asset in work settings, social interactions and even a quest to attract the opposite sex.[4,5]

Subject of smile and facial animation as it relates to communication and expression of emotion should greatly influence orthodontist. Orthodontic intrusion is a common treatment approach in managing orthodontic esthetic and functional problems, including gummy smile and deep bite.[6] It has been proposed that curvature of the incisal edges of the upper anterior teeth and curvature of the upper border of the lower lip should be in harmony and this curvature is called as smile arc.[6,7]

Most orthodontist often come across cases with excessive incisor exposure and increased overbite in their clinical practice. These patients require a comprehensive treatment plan, which establishes how the incisor exposure should be reduced and deep overbite corrected, depending on the cause.[8-10] Generally, intrusion as an orthodontic therapeutic manipulation may mean following: orthopedic intrusion referring to superior displacement or, even better,

to inhibition of inferior movement of the maxillary complex and it is achieved with the use of functional appliances or high pull headgear with or without a functional appliance; surgical superior maxillary displacement in cases of vertical maxillary excess (VME); and intrusion of a single tooth or groups of teeth.[10-14]

The first two categories concern growing and adult patients and include complex skeletal and dentoalveolar changes. However, pure dental intrusion in growing individuals or adults constitutes a basic therapeutic strategy of many orthodontic techniques (bioprogressive) or certain "schools" of treatment (Begg) for managing deep bite. Even more often, intrusion occurs, to a certain extent, almost always spontaneously during orthodontic treatment, given that, irrespective of the therapeutic technique, wire activation at the time of ligation on two teeth with height difference leads to intrusion of one tooth and extrusion of the other. Thus, orthodontic intrusion is encountered in almost all treatment types and is often not the clinician's choice.[14]

TYPES OF INTRUSION

Relative intrusion

It is achieved by preventing eruption of the incisors while growth provides vertical space into which the posterior teeth erupt. There is pure intrusion of the incisors without extrusion of the posterior teeth. Relative intrusion of the incisors is accomplished by labial tipping of the incisors and extrusion of other teeth in the arch, without any actual intrusion, as the diagram shows.

Therefore, in the levelling phase any wire can relatively intrude teeth. However, an intrusion wire, is used when there is a necessity for absolute intrusion of teeth, where tipping and extrusion of other teeth is not in demand.[15-17] Methods of relative intrusion include anterior bite plates contacting the anterior dentition while allowing posterior eruption; twin-blocks, where differential molar eruption can occur by trimming the posterior blocks; anterior bite turbos; and reverse curve of Spee.[16]

Absolute intrusion

There is pure intrusion of the incisors without extrusion of the posterior teeth. It requires a mechanical arrangement other than a continuous archwire attached to each tooth. Light continuous force directed toward the toot apex is the key to successful intrusion. Incisors being intruded, using the molars as anchorage as the diagram shows.

There is an equal and opposite extruding force occurring on the molars, as with every force in orthodontics. Pure absolute intrusion is preferable accomplished with the use of mini-implants. Methods of absolute intrusion include are J-hook headgear, bypass and segmental mechanics and temporary skeletal anchorage (micro-implants).

INDICATIONS FOR ORTHODONTIC INTRUSION

Gummy smile

The most common indication for dental intrusion concerns the management of deep bite, which may be combined with gummy smile of varying degrees. More specifically, in cases where bite opening with orthodontic eruption of posterior teeth using biteplates or cervical headgear is contraindicated or is unsuccessful, deep bite correction may only be achieved with intrusion of the anterior teeth. Patients with increased overjet and lower facial height, showing at the same time a gummy smile and incisor exposure at lip rest, as in class II, division 1 malocclusion, are perfect candidates for intrusion in order to improve esthetics.[18-20]

Deep bite and reduced lower facial height

The outcome of orthodontic eruption is not stable, especially in adult patients with a small mandibular plane angle and strong masticatory system as shown clinically by the presence of strong masseter muscles and a rectangular face, due to the increased vertical component of the biting force that affects the stability of posterior eruption.[21,22] On the other hand, in patients with severe deep bite and minimal exposure of incisors at smiling, correction should include careful intrusion of lower incisors in order to avoid further concealment of upper anterior teeth at smiling. Alternatively, and depending on the degree of deep bite, posterior orthodontic eruption with the use of an anterior biteplate is recommended, so that part of the correction is achieved without intrusion.

Deep bite and increased lower facial height

In the rare cases where the dental deep bite is combined with a skeletal background of increased vertical growth and clinical "open bite tendency", posterior orthodontic eruption should be avoided due to an increase of the mandibular plane angle.[23] Incisor intrusion is also necessary in cases of extrusion of maxillary but, especially, mandibular incisors often observed in class II, division 2 malocclusion. In these cases, esthetic improvement is important mainly due to restoration of the gingival line.[24,25]

Intrusion of periodontally involved teeth

The most common pathologic cause of extrusion is periodontal disease, which in advanced stages results in clinical crown lengthening and spacing of the teeth, thus, further compromising the esthetics of smiling.[26,27] In general, orthodontic treatment in periodontal patients is a contradictory issue. Many authors dispute the benefits of such an approach and claim that it has negative effects on the periodontium, whereas others support the view that orthodontic treatment inhibits the progression of osseous loss.[28,29] More recent studies conclude that a combination of periodontal treatment and orthodontic intrusion may

improve periodontal status, given that the mechanics used and oral hygiene are carefully controlled.[30,31] More specifically, use of light orthodontic forces is recommended because, as bone loss progresses, periodontal support is reduced and the same force now induces greater stress on the periodontal ligament as compared to a tooth with normal tissue support.[32-36]

Intrusion of posterior teeth

Similar treatment is necessary in cases of extrusion of posterior teeth due to early loss of their antagonists, to prosthetically restore teeth of the opposing arch. In this case, and depending on the degree of extrusion, endodontic treatment and occlusal crown reduction or even, in rare cases, osteotomy may be needed. In general, the extent of intrusion depends on anchorage and may include absolute or relative intrusion, depending on the severity of the occlusal and esthetic problem.

Optimal intrusive force for intrusion

Intrusion must be performed carefully in adults, lamina dura of adult teeth in the apical region is frequently denser and periodontal ligament is somewhat narrower than in children's teeth. A careful examination of radiograph is always important for intrusion. Loading diagram, of intrusive force shows that force is concentrated over a small area at the apex. For this reason, extremely light forces are needed to produce appropriate pressure within the periodontal ligament during intrusion.[15]

An optimal force is one that produces a rapid rate of tooth movements, without discomfort to the patient or ensuing tissue damage. Optimal force range for intrusion has been a long time controversy. Dellinger in 1967, demonstrated intrusion histological and cephalometrical for the first time on monkey premolars when he applied 50 grams of force and found very little resorption with good intrusion. Stenvik and Mjor in 1970 investigated the effect of intrusion on pulp and dentine on human premolars and found that force above 150 to 200 grams caused stasis in pulp vessels. Reitan in 1974, did studies on the intrusion of human premolars and concluded that force around 80 to 90 grams range caused apical root resorption while any force not exceeding 30 grams did not result in any damage. Burstone in 1977, suggested 50 grams of intrusive force for upper central incisors, 100 grams for central and laterals and 200 grams for six upper anteriors. He advocated use of 40 grams for four lower incisors and 160 grams for all six lower anteriors. Bench, Gugino and Hilgers in 1978, advocated intrusive force of 15 to 20 grams per lower incisor and 60 to 80 grams for all four lower incisors. Ricketts in 1980 advocated use of 125 to 160 grams of force for upper incisor intrusion and 60 to 75 grams for lower incisors. Lui and Herschelb in 1981 suggested use of 80 to 100 grams of force for four incisors intrusion.

Nicolai in 1985 suggested that intrusive force should be 60 grams/cm^2 of occlusoapical projection of root surface area. Kesling in 1985 suggested 35 grams of net force for six upper anterior intrusions, 14 grams for lower six anteriors. Proffit in 1993 suggested 15 grams of force needed for incisor intrusion. Siatkowski in 1997, based on the work of Dermaut suggested 10-15 grams of force for upper central incisor whereas 5-10 grams for lower lateral and 15-25 grams for canines. Though there have been many opinions regarding an ideal force for intrusion, all recognize the need for light continuous force

BIO-MECHANICS OF INTRUSION (ANALYSIS OF BIOMECHANICAL SITUATION)

True intrusion is obtained when an intrusive force is directed through the center of resistance of the anterior teeth. Unfortunately, this is difficult to accomplish; spatial relationship between center of resistance (CR) and point of application varies depending on labiolingual inclination of upper incisors. Intrusive force is normally applied to the labial surface of the incisors, this produces a moment which tends to flare the crowns forward and move the roots lingually. In cases where incisors are markedly proclined, an intrusive force creates a large moment. In these cases, incisors should be retracted first to improve their axial inclination before intrusive mechanics are initiated. Thus the key to successful intrusion is light continuous force, which is directed towards the root apex of incisors.[15]

Biomechanics of intrusion arches

Law of equilibrium states that for every force there is an equal and opposite reactive force, but also that sum of the moment in any plane is equal to zero. In other words, moments as well as forces generated by an orthodontic appliance must be equal to zero.[21] Analysis of equilibrium can be stated in an equation form.

$\Sigma Horizontal\ forces = 0$

$\Sigma Vertical\ forces = 0$

$\Sigma Transverse\ forces = 0$ and

$\Sigma Moment\ (horizontal\ axis) = 0$

$\Sigma Moment\ (vertical\ axis = 0$

$\Sigma Moment\ (transverse\ axis) = 0$

ONE COUPLE AND TWO COUPLE SYSTEMS

Determinate systems in orthodontics are those in which a couple is created at one end of an attachment with only a force (no couple) at the other. This constitutes the one couple system; which means that the wire, which will serve as a spring, can be inserted into a tube or bracket at one end, but must be tied so that there is only one point of contact on the other. When more is tied into the bracket on

both ends – a statistically indeterminate two couple system has been created.[5]

One couple system

In orthodontic applications, one couple systems are found, when two conditions are met. Cantilevers spring or auxillary arch wire is placed into a bracket or tube. It typically attaches to a tooth or teeth that is part of the stabilized segment. Other end of cantilever spring or auxillary arch wire is tied to teeth that are to be moved with a single point of force application like an intrusion arch.

Intrusion arches

Major use of one couple systems is for intrusion, typically of incisors that have erupted too much. For intrusion, light force against the teeth to be intruded is critical. Intrusion arch typically employs posterior anchorage against two or four incisors. Because the intrusive force must be light, the reaction force against the anchor teeth is also light, well below the force levels needed for extrusion and tipping that would be the reactive movement of the anchor teeth. Tying the molar teeth together with a rigid lingual arch prevent buccal tipping of molars.

Two factors in the action of the intrusion arch are the relationship of the point of force application relative to the center of resistance of the incisor segment, and whether the incisors are free to tip facially as they intrude or whether the arch is cinched back to produce the lingual root torque. First factor, an intrusion arch can be tied at any point along the incisor segment. If it is tied behind the lateral incisor bracket, the force is applied in line with the center of resistance, and there is no moment to rotate the incisors facio-lingually. Second factor, if the intrusion arch were tied in the mid line and cinched back so that it would not slide in the forward in the molar tube, the effect would be lingual root torque on the incisors as they intrude. Equilibrium requires that both moments and forces be balanced, so the moment on the incisors would be balanced by similar moments on the anchor molars. Each would receive a 100 gm-mm moment to bring the crown mesially, which would require a 10 gm force at the distal of the molar tube, if the distance from the tube to the molars center of resistance were 10 mm.

Two couple system

The effect of tying an intrusion arch into the brackets changes the bio – mechanical aspect of the appliance from a one couple system to an indeterminate two couple system. Utility arch popularized by Ricketts and used frequently for incisor intrusion, makes this change. Like a one-couple intrusion arch, it is formed from rectangular wire so that it will not roll in the molar tube, and it bypasses the canine and premolar teeth. The resulting long span provides excellent load deflection properties so that light force necessary for intrusion can be created. Difference comes when utility arch is tied into the incisor brackets.

Utility arch often is an intrusion arch in a two couple configuration, created by tying the intrusion arch into the slots of the brackets. When this is done, the precise magnitude of the force and couples cannot be known. Activating the utility arch, by placing it into the brackets creates the intrusive force, with a reactive force of the same magnitude on the anchor molar and a couple to tip the crown distally. At the incisors, a moment to tip the crown facially (M_f) is created by the distance of the brackets forward from the center of resistance, and an additional moment in the same direction is created by the couple within the bracket (M_c) as the inclination of the wire is changed as it is brought to the brackets. The moment of the couple cannot be known, but is clinically important as it affects the magnitude of the intrusion force. Placing a torque bend in the utility arch creates a moment to bring the crown lingually, controlling the tendency for the tooth to tip facially as they intrude, but it also increases the magnitude of the intrusive force on the incisor segment and the extrusive force and the couple on the molar.

Cinching back the utility arch creates a force to bring the incisors lingually, and a moment of this force opposes the moment of the intrusive force. At the molar, a force to bring the molar mesially is created along with a moment to tip the molar mesially. Especially if the torque bend is present, it is difficult to be certain which of the moments will prevail, or whether the intrusive force is appropriate. With this two-couple system, vertical forces easily can be heavier than desired, changing the balance between intrusion of incisors and extrusion of molars.

MAJOR PRINCIPLES OF INTRUSION

Six major principles of intrusion should be followed; if genuine intrusion and greater control of force system is needed.[37]

Controlling force magnitude and constancy

It is important to use the lowest magnitude of force that is capable of intruding incisors. If the magnitude of force is too great; rate of intrusion will not increase and rate of resorption will increase as demonstrated by Dellingers research on monkeys.

Too great a force will have reciprocal effect on posterior anchorage, posterior teeth will feel a vertical force which will tend to extrude the buccal segment and a moment which in upper arch will steepen the plane of occlusion and in the lower arch flatten it. If only a single tooth, as the 1st molar is attached to an intrusive spring, the undesirable side effect is only a tip back action with the crown moving distally and root mesially. Loss of anchorage during intrusion is primarily produced by moment rather than by force since occlusal forces tend to negate eruptive tendency.

To maintain a constant force during intrusion, wire with a low load deflection rate should be used. If a high load

deflection spring is used for intrusion as teeth moves, a rapid drop in force magnitude occurs, so that optimal force may be only momentarily reached. Suggested force levels are based on clinical experience and the clinician learns that to accomplish optimum intrusion, force should be delivered constantly. A low load deflection rate spring makes it practical for the clinician to determine the magnitude of force, since activation is not so critical and as intrusion proceeds there will not be marked reduction in force magnitude.

Anterior single point contacts

Anterior single point contact is needed in the anterior segment so that a constant force is produced and genuine intrusion is produced in the anterior segment. By having a single point of force application on the incisors, the clinician knows more positively the full force system acting at the incisor segment and buccal tube, thereby producing a statically determinant system. By placing the intrusive arch into the brackets produces a statically indeterminant system, which prevents the orthodontist from knowing exactly what type of force he is delivering.

Intrusive arch is not placed directly into the brackets of anterior teeth; because anterior torque may be present in the arch even if no torque is present as the intrusive arch works; torque can be introduced. If inadvertently or purposely labial root torque is placed into the incisors; intrusive forces are increased on anterior teeth, the added intrusive force is not needed and can produce anchorage loss of posterior teeth. Undesirable curvatures are formed in the wire during activation if the intrusive arch is placed directly into the anterior segment. Anterior single point contact allows for placement of series of anterior alignment arch directly into the bracket. An exception in which intrusive arch may be placed into the brackets of incisors can be found in the example of central incisor intrusion alone. If the intrusive arch is placed into the incisors, it is necessary to round the wire so that no torque is produced. Rounding the anterior segment of an intrusive arch going into four incisors may be a problem since torque can still be produced because of curvature in anterior part of the arch.

Point of force application

An intrusive force placed through the center of resistance of the incisors will intrude the teeth and not produce any labial or lingual rotation of teeth. Center of resistance of an anterior segment can be estimated to be at the geometric center of roots of the incisors to be intruded. For an anterior segment comprising of two central incisors, center of resistance was located on a projection line parallel to mid saggital plane on a point situated at distal half of the canine. For an anterior segment that included the four incisors, center of resistance was situated on a projection line, perpendicular to occlusal plane between canines and 1st premolar.

For rigid anterior segment that included the six anterior teeth, center of resistance was situated in a projection line perpendicular to occlusal plane distal to the Ist premolar.

Center of resistance of anterior segments incorporating two or four anterior teeth were within 2 mm of each other, however inclusion of canines in anterior segment resulted in center of resistance moving distally by approximately one premolar width (7 mm). No appreciable shift in location of center of resistance of various segments was studied as varying magnitude of intrusive force was applied. In maxillary intrusion, intrusive arch is normally placed slightly anterior to labial surface of incisors as it is attached to the anterior segment. This produces a moment which tends to flare, the crowns forward and move the roots distally. It is therefore important to tie the intrusive arch back to prevent the incisors from protruding. When the intrusive arch is placed anterior to center of resistance during intrusion, root retraction simultaneously occurs and minimizes the need in many class II patients for root movement to be accomplished in a later stage.

Control of reactive units

Best control over the posterior teeth, is the minimization of force magnitude used for intrusion. Since the moment arm is so large from anterior to posterior segments, it is necessary to give thought to control of posterior teeth. Posterior teeth are joined together to form the posterior anchorage unit. Whenever possible at least the first molars and second premolars should be used and addition of other teeth would enhance anchorage. The potential wire used for stabilizing the buccal segments should be atleast 0.018" square in cross-section for 0.022" slot brackets and in addition the right and left buccal segments are joined with a trans-palatal arch in maxilla and lingual arch in the mandible.

Two basic side effects should be anticipated from intrusive mechanics. First side effect is that from the lateral view a moment is created which tends to alter the plane of occlusion of the buccal segment and therefore in the upper arch, the plane is steepened. To minimize these changes a number of principle are used in the intrusive mechanics that have been described, the force is kept as low as possible, teeth in the buccal segment are rigidly connected and the right and the left buccal stabilizing segment are connected by a trans-palatal arch in the maxilla and by lingual arch in the mandible.

Finally, as an added precaution occipital head gear can be used in the upper arch. Second major side effect produced by an intrusive arch can be seen from the frontal view with an intrusive force acting on the incisors, there is an equal and opposite extrusive force acting at the molars and since the extrusive force is acting buccaly at the tube, a moment is created that tends to tip the crowns lingually and roots buccally. One of the functions of the lingual arch is to resist side effects and to prevent any undesirable change in axial inclination of molars or change in width.

Control of extrusive mechanics

Extrusive mechanics should be avoided if one is to accomplish genuine intrusion. Examples of extrusive mechanics include use of class II and class III intermaxillary elastics, cervical headgear with outerbows placed above the occlusal plane and placement of reverse curve of spee in lower arch to extrude premolars. One of the classic situations for inadvertently erupting incisors, which have been intruded or are going to be intruded is placement of continuous arch wire. If the arch wire is placed into the canine bracket, it will lie occlusal and hence will produce extrusion of incisors. Incisors make very poor anchorage for distal root movement of canine, since eruption occurs much more easily than distal root movement. It is therefore preferable to bypass canines during canine root movement or in certain situation canine root movement should be completed, before incisors are joined to rest of the arch.

Selective intrusion

Taking advantage of geometry of anterior segment is one of the key concepts in producing genuine intrusion. In class II division 2 cases, occluso-gingival steps are seen in the position of the incisors as upper central incisors project occlusally to the lateral incisors. It is desirable to intrude just the two central incisors to the level of lateral incisors before joining all four incisors together for further intrusion. When one works on two incisors alone, lower forces can be used, and undesirable side effect that are present with continuous arch are avoided. A continuous arch placed through the brackets not only produces vertical forces but, unfortunately creates moments which alter axial inclination as result of which extrusion and steepening of maxillary plane would occur, which results in deepening of overbite.

In a similar way class II division I patients may require intrusion of four incisors, both maxillary and mandibular, to the level of canines. Many times canines that are in infraocclusion should not be extruded but the four anterior teeth should be intruded to the level bypassing the canines. Indiscriminate levelling of anterior segment with a continuous wire may make it impossible to employ intraoral mechanics.

CONCLUSION

The components of comprehensive orthodontic treatment, primarily alignment, overbite control, space closure, root paralleling, and finishing rely on a series of biomechanical processes. The choice of appliances and techniques used by practitioners varies radically among individuals, but the fundamental forces and moments they produce are universal. Appliances will always act according to the laws of physics. Therefore, understanding the basic biomechanical principles of intrusion may help in effecting-controlled tooth movement and helps in achieving successful orthodontic treatment outcomes more predictable and consistent.

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