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Chapter 5

Orthodontic Considerations in Surgical Interventions for Impacted Teeth

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/59143

1. Introduction

Parallax is the effect whereby the position of a tooth or similar structure appears to differ when viewed from different positions of the X-ray tube.[1] This method (Image/Tube Shift Method, Buccal Object Rule or Clark's Rule) has been the technique of choice to localize impacted teeth anterior to the molars in both jaws using Vertical or Horizontal Tube Shift (VTS /HTS).[2] With the continued technologic advances, the role of Cone Beam Computed Tomography (CBCT) is changing in orthodontic workup and should be viewed as complementary to plain X-rays or 2D X-rays in effective diagnosis, especially in impaction cases as a 3D evaluation. Effective dose of radiation measured in micro-Sievert (μSv)) is decreased from full field of view (FOV) to both jaws (13 cm) and single jaws (6 cm), from large-volume to small-volume and from high resolution (HR) to conventional.[3] Therefore, as the effective dose is of foremost concern, it can be decreased by appropriate selection of exposure parameters, FOV and resolution (only for impacted tooth/teeth) to be comparable from a "dose" perspective with several periapical and occlusal radiographs (parallax). However, the results of dosimetry on a specific CBCT scanner may not be transferable to another CBCT scanner and every image involving ionizing radiation, including CBCT, must be justified and optimized.

The treatment (including decision makings) of impacted teeth can be categorized into five steps:

1. Cost-Benefit Analysis/ Cost-Effectiveness Analysis
2. Space preparation/Barrier removal
3. Selection of the method for eruption (Closed vs. Open)

4. Selection of the appropriate (effective) biomechanical approach
    a. Anchorage preparation (Direct vs. Indirect)
    b. Force application
5. Alignment/ Leveling Torque/Angulation (ALTA) corrections

2. Cost-Benefit Analysis (CBA)/ Cost-Effectiveness Analysis (CEA)

Cost-benefit analysis (CBA) or Cost-effectiveness analysis (CEA) requires quantifiable input data; both methods are accounting techniques that have been applied to medical decision-making. Using Standard CEA, benefits are expressed either directly or indirectly in terms of "quality of life" improvement, and costs are expressed in monetary values and in morbidity and mortality. Using CBA, benefits and costs are all converted into monetary equivalents.[4] The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a project or decision i.e. exposure of impacted tooth and ALTA correction versus alternative treatment modalities. Results must be treated with caution, making it difficult to make robust claims about the comparative cost-effectiveness of either treatment plan.

Systemic conditions or metabolic disturbances may be related to multiple impacted teeth. To achieve optimum results, an interdisciplinary teamwork is needed between the orthodontist, oral surgeon, prosthodontist and possibly some other specialties. The patient shown in Figure 1 an active social person, had several impactions in both jaws but was seeking a swift procedure to get his anterior teeth. The facial profile, esthetic smile, and time spent for each appointment in a nonprofit dental center were also among his concerns. It seems that the selected option for the patient had more benefit gain in comparison to cost (time, pain, inconveniences, and risks and...etc.).

In the first step clinicians should make a decision from the CBA/CEA perspective to select the best option appropriate for the individual looking for treatment of the impacted tooth/teeth.

2.1. Early intervention for impaction prevention

Space deficiency has been mentioned as the first etiologic factor for a palatal impaction. Many other contributing factors are associated with a palatal impaction such as over-retention of the primary canines, abnormal position of the tooth bud, disturbances in tooth eruption, localized pathologic lesions, abnormal sequence of eruption, missing lateral incisors or abnormal form of the lateral incisor roots (e.g. dilacerations), presence of an alveolar cleft, supernumerary tooth, and idiopathic factors.[5]

Crowding, thick soft tissue, supernumerary tooth/teeth, and tipped tooth/teeth situations are considered as barriers to eruption. During the regular orthodontic examination of a patient (Figure 2) an impaction was discovered on panoramic radiography suspected to be an abnormal position of the tooth bud but proximity of developing root of tooth 14 and crown of #13 (FDI Two-Digit Notation- ISO 3950) in addition to their abnormal route are the major

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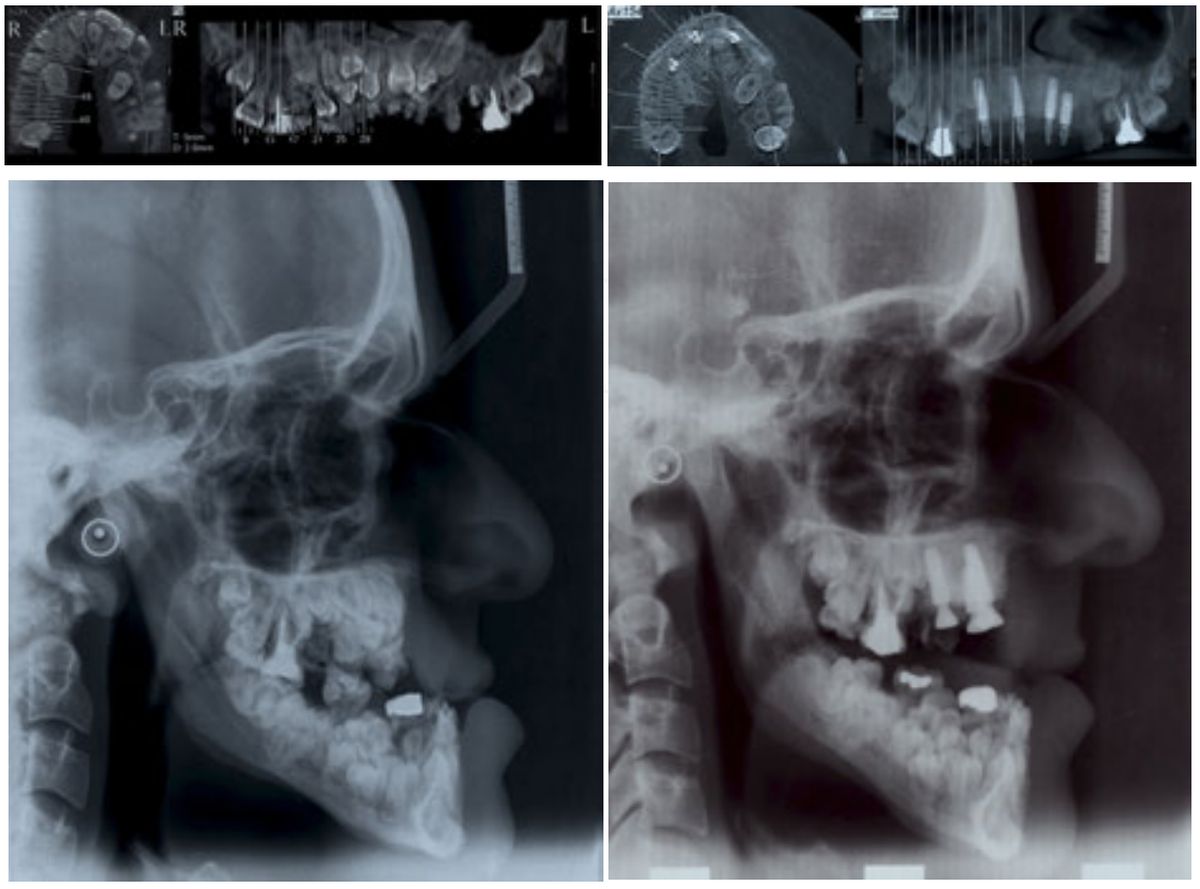

Figure 1. Cost versus benefit appraisal for the above patient was considered according to the duration of the treatment versus time needed to receive anterior implants and reliability of this option. Multiple impacted teeth were extracted and after placement of allograft based bone graft substitute, four dental implants were inserted. The patient continued his treatment and the implants were used as anchorage for extruding mandibular impacted teeth.

concerns. It was postulated that rapid developing root with differentiating cells of the dental papilla plus vascular pressure toward malposed erupting crown of tooth 13 had caused both teeth to deviate from their normal route. After extraction of the upper right first primary molar, the pressure was relieved. By using a banded expander and extraction it seems that more space was provided for erupting teeth and the impacted canine is getting more vertical relative to the initial radiograph.

2.2. Difficulty index as a tool for expression of the "Cost"

The canine is the second most commonly impacted tooth (after the third molar), with the rate of maxillary canine impaction ranging from approximately 1% to 3% [6] and incidence of approximately 20% in orthodontic clinics. Should you ALTA correction of tooth at the expense of extra time and money or extract the impacted tooth, saving time and orthodontic payments for the patient but perhaps at the expense of esthetics and long-term function.

When treating impacted teeth, duration of treatment or chairtime, success rate or risks, and complcations (root resorption of impacted or adjacent teeth, ankylosis,..) can be converted to

to initial radiograph.

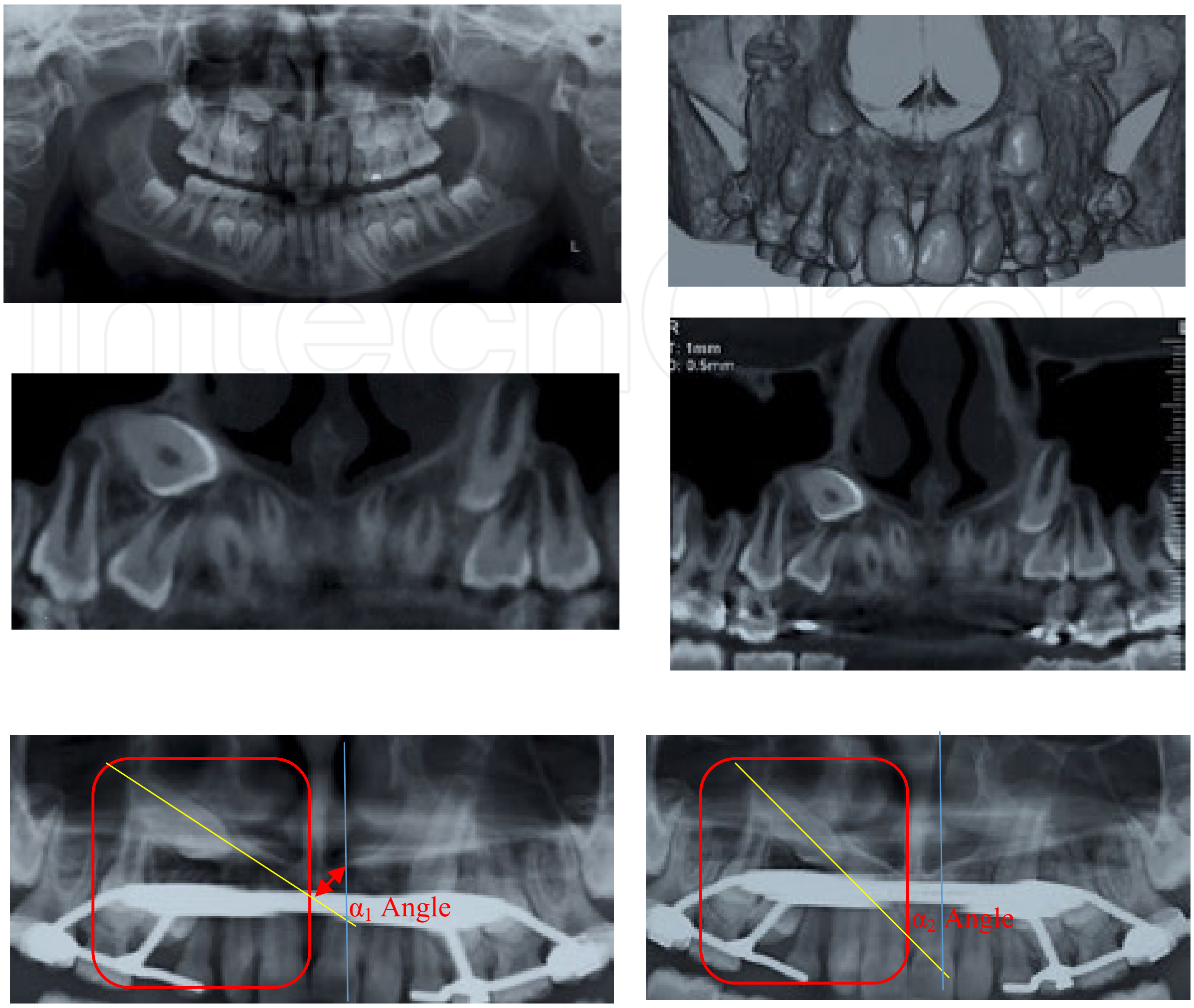

Figure 2: Impacted canine has angulated towards the horizontal (Top-right) and made the management more challenging and difficult. Impacted tooth 13 has tipped toward a better vertical position (Bottom left to bottom right) in other words Alpha (α) angle is decreased after banded expander installed and tooth 54 (D) was extracted ($\alpha_1 > \alpha_2$).

a single score that would be compared to the benefits. However, sensitivity and specificity of these scores or methods are uncertain and questionable. Many variables have role in determination of difficulty for impaction cases including age (over 25 requires longer time), distance of impacted tooth from occlusal plane, mesiodistal location of the crown, angulation of the tooth, transverse relationship of the crown to the midline, location of the impacted tooth cusp/incisal tip and its relationship to the adjacent teeth (lateral incisor in canine impaction cases), apex position, and transposition with adjacent teeth (lateral incisor and first premolar in canine impaction cases).[7] Angular measurements on lateral cephalometry are Omega (ω) angle and Delta (δ) angle and linear measurement is d2 (Distance to Occlisal Plane) (Figure 3). Angular measurements in panoramic views are the canine inclination (C.I.) to midline or Alpha (α) angle and its inclination to the lateral incisor (or first premolar) or Beta (β) angle (Figure 4-second row). Mesiodistal position of the canine cusp tip in relation to adjacent lateral and central incisors on panoramic radiographs is called "Zone" and numbers 1 to 5 are assigned to its position as it gets closer to the midline (Figure 4-third row).[6] Inclination of the canine

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in the horizontal plane or the degree of mesial orientation of the canine is analyzed by measuring the Gamma (γ) angle between projection of long axis of the canine and the midline of the maxilla in axial CBCT slice of maxilla (Figure 4-bottom left)

In quantitative terms, the larger the relative risk, the more likely the association is causal. When studying causative factors, it is very important to analyze the strength of the association in addition to the significance. More advanvce canine development, a more medial position of the canice cusp, considering the zones [1-5], and mesial inclination of the canine to midline exceeding 25° (α angle) are powerful factors.[8]

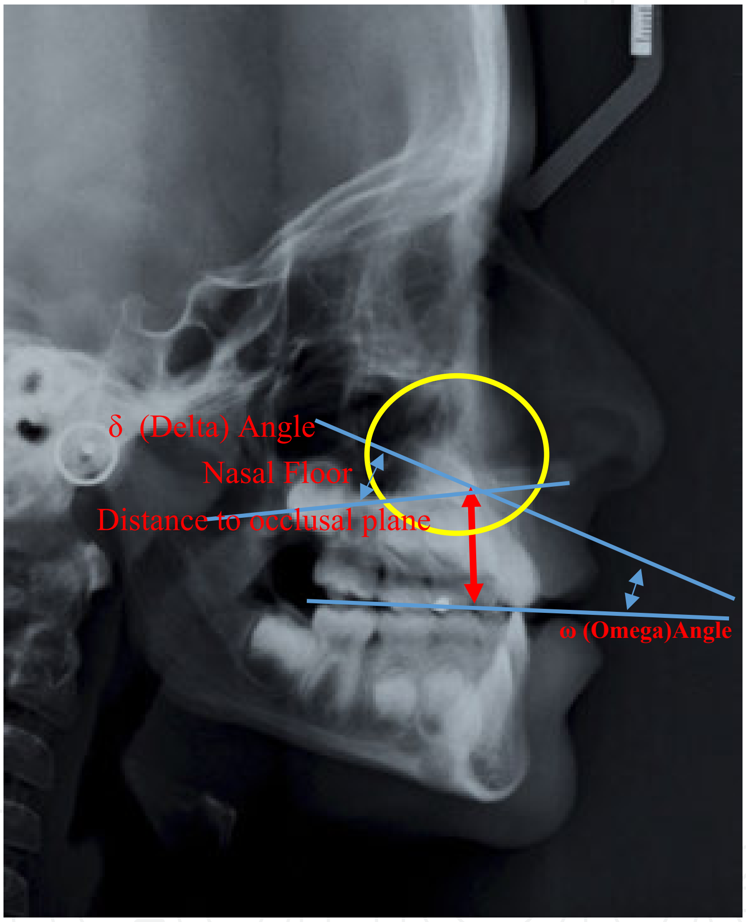

Figure 3. Angular measurements or inclinations of the canine in the sagittal plane are Omega (ω) angle and Delta (δ) angle (path of eruption) and linear measurement is d2 (Distance to Occlisal Plane).

Regression analysis indicated that horizontal position, age of patient, vertical height and bucco-palatal position, in descending order of importance, are the factors which determine the difficulty of canine alignment.[9]

Sector location and angulation of the unerupted tooth have been analyzed previously as predictors of canine eruption after deciduous extraction. Additionally, sector location has been studied as an indicator of eventual impaction, resulting in good predictive success (Figure 5).[10] Different indices provide useful treatment planning aid for the management of impacted

maxillary canines like treatment difficulty index (TDI) [9] and 3D cone beam CT based classification system for canine impactions (the KPG index).[11]

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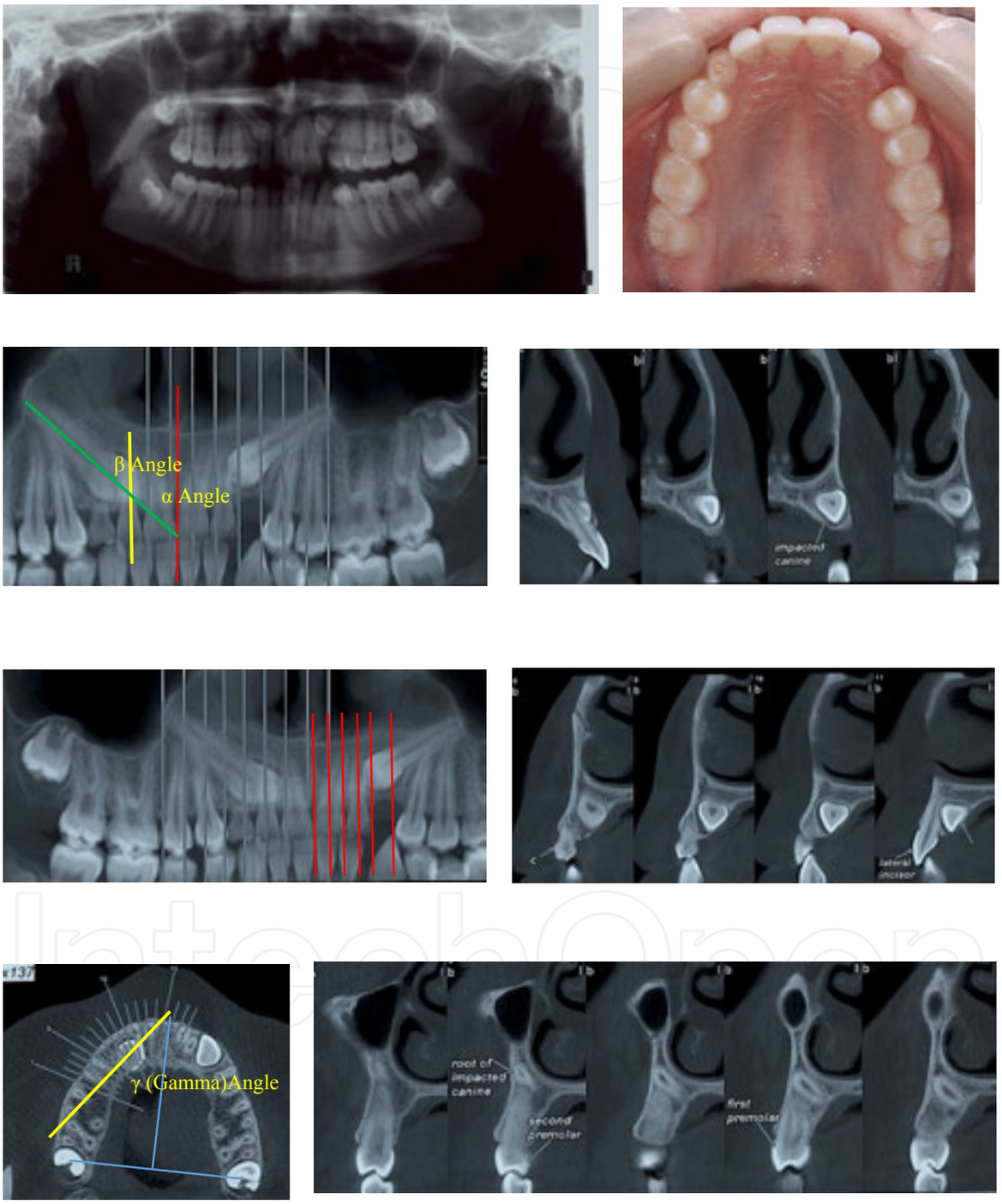

Figure 4. Angular measurements in panoramic views are the canine inclination to midline or Alpha (α) angle and its inclination to the lateral incisor or Beta (β) angle (second row). Mesiodistal position of the canine cusp tip in relation to adjacent lateral and central incisors on panoramic radiographs is called "Zone" (third row). Inclination of the canine in the horizontal plane or the degree of mesial orientation of the canine is analyzed by measuring the Gamma (γ) angle between projection of long axis of the canine and the midline of the maxilla (bottom left).

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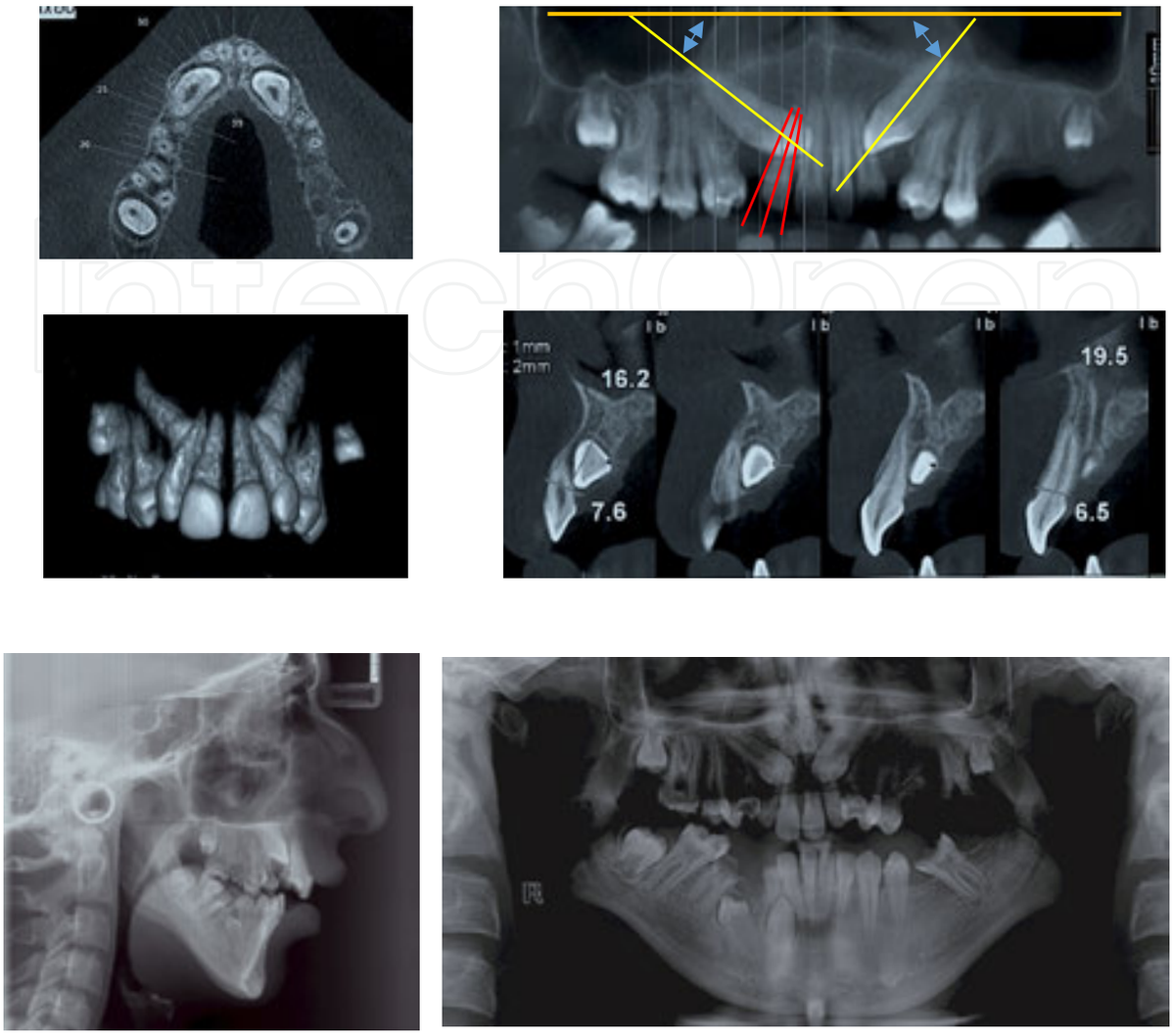

Figure 5. Sector I represents area distal to line tangent to distal heights of contour of lateral incisor crown and root. Sector II is mesial to sector I, but distal to bisector of lateral incisor's long axis. Sector III is mesial to sector II, but distal to mesial heights of contour of lateral incisor crown and root. Sector IV includes all areas mesial to sector III (3 red line- Top right). The most superior point of the condyle was selected as a landmark, a bicondylar line was then drawn and used as a constructed horizontal reference line. The measurement was taken of the mesial angle formed by using the constructed horizontal and the long axis of the unerupted tooth (Top right).

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3. Space preparation/Barrier removal

2- Space preparation/Barrier removal

Space is needed (space available) for bringing teeth (teeth materials) into the dental arch. Many mechanisms exist for creating the adequate space including Stripping mesial or distal enamel of the teeth (proximal) with condition of existing Bolton discrepancies between upper and lower dentition, Extraction of premolars, incisors with condition of Bolton ratio considerations, or decayed teeth, Derotation or Uprighting of the posterior teeth after extractions or in the missing teeth conditions, proclination of anterior teeth, distalization of the posterior teeth, Orthopedic (Maxilla) or Orthodontic Expansion of dental arches.

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Constricted arches, dental irregularities, proclinations of teeth relative to jaw bases or patient profile, deep bites and open bites with tight contacts between the teeth should be considered as space deficiency or crowding. Reproximation or proximal stripping produces up to 3.5 mm of space and 1 mm of expansion in the posterior part of maxilla is capable to produce 0.7 mm increase in arch perimeter that can be used for crowding resolution.

Upper dental arch expansion and lower dental arch uprighting (from lingual side to buccal side) produce space for bringing the impacted teeth to the dental arch. After full bonding of the arches, by incremental increase in wire diameter plus changes in cross sections (from round to rectangular) and material (from NiTi to Stainless Steel); dental arches begin to get adapted to final wire shape and size from its lingually collapsed cases to the consequent expanded arch.

Maxillary expansion can be skeletal or orthopedic if it is conducted in appropriate time i.e. before fusion of palatal suture. For maxillary expansion, banded expander (with Hyrax screw and acrylic free palate), banded+bonded (occlusal acrylic coverage) expander, and banded +palatal acrylic (Haas type) expander can be used for both dental and skeletal expansions.

In addition to space regaining in dental arches, physical barriers as supernumerary teeth, odontomas, or other pathologic lesions that inhibits tooth eruption; should be removed. Apart from hard tissue lesions, soft tissue fibrotic hyperplasia or thick fibrotic gingiva can prevent regular tooth eruption and they can be treated surgically or by laser beam.

4. Selection of the method for eruption of impacted tooth (Closed versus Open)

Method of exposure is very important to be practical for the surgeon, to be useful for application of biomechanical forces for the orthodontist, and to be beneficial for the patient. Benefits for the patient consist of several immediate and future outcomes; including periodontal health, esthetics, and stability of treatment. Facio-lingual and vertical position of the impacted teeth are very important in determining an appropriate approach for exposure. Buccally/Labially impacted teeth can be accessed after apically positioned flap or closed eruption technique. Excisional uncovering or gingivectomy necessitates special conditions including superficial position of tooth (vertically and facio-lingually), and adequate width of keratinized gingiva. An example of inappropriate surgical approach for uncovering the impacted central is conducting the procedure apical to the mucogingival junction and removing the keratinized gingiva (Figure 6).

Apically positioned flap (Open) or closed eruption technique is an aid for maintenance of the biologic width. The biological width is comprised of epithelial attachment and connective tissue attachment (both dimensions added) coronal to the crest of the alveolar bone. It should be planned to preserve an adequate apico-coronal height of keratinized gingiva (2-3 mm), especially in the presence of thin gingival biotype (transparency of the periodontal probe through gingival margin). In some cases impacted teeth are superficial and coronal or near mucogingival junction, in these circumstances, an apically positioned flap or open approach

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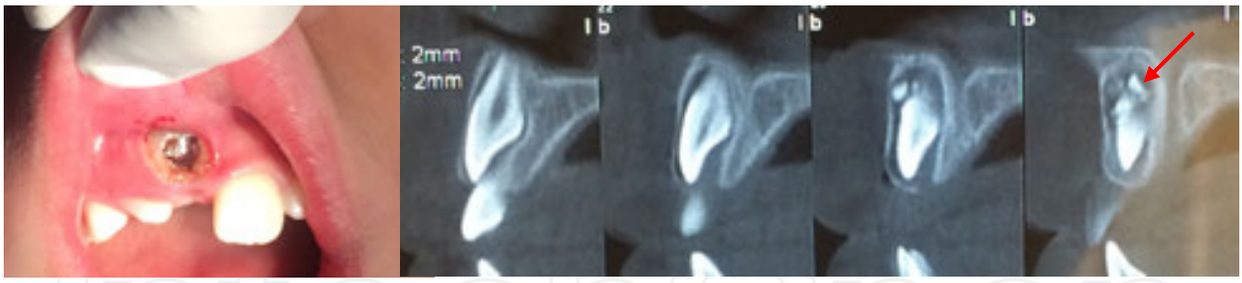

Figure 6. An inappropriate order to expose the impacted left central incisor. Incorrect technique is independent of tools i.e. laser beam or scalpel; a required width of attached gingiva (necessary for periodontal health) has been removed to create a buttonhole window (Left-clinical) as an unaccepted procedure with a bonded attachment. On the first right slice of CBCT, an odontoma-like malformation is obvious but has been neglected during the surgical intervention (red arrow).

Figure 6. An inappropriate way to expose the impacted left central incisor. Incorrect technique is independent of tools i.e. laser beam or scalpel; a required width of attached gingiva (necessary for periodontal health) has been removed to create a buttonhole window (left) as an unaccepted procedure with a bonded attachment. On the first right slice of CBCT, an odontoma-like malformation is obvious but has been neglected during the surgical intervention (red arrow).

is indicated but the author suggests minimum apical repositioning of the flap equal to the amount needed for bonding of an orthodontic bracket in proper position for avoiding future apical migration of the gingival margin. Uneven gingival contours can be corrected by cosmetic periodontal plastic surgery (laser, scalpel, or radiosurgery) if adequate soft tissue exist. Uncontrolled tipping toward labial/buccal can produce gingival/bone recession plus a long clinical crown that should be avoided.

When impacted teeth need a facial (labial or buccal) approach, and the position of tooth is deep, closed eruption is an option. In the aforementioned situation, an apically positioned flap will not be stable and rebound of soft tissue may occur in addition to unwanted exposed parts of the bone that should be covered by a flap (Figure 7).

During tooth exposure, care should be given to protect root surface, for example; by avoiding the usage of sharp or rotary instrument if possible because bone and the unerupted tooth are color matched and any damage to the root leads to periodontal ligament breakdown, increased risk of ankylosis, and increased risk for future bone and gingival recession (deleterious effects to periodontal health and esthetics). Thin layers of bone can be removed by periosteal elevator or similar instruments e.g. curette to reach the coronal part of the tooth (Figure 7).

Soft tissue covering the hard palate is called masticatory mucosa and it consists of keratinized stratified squamous epithelium. Since the palate is covered with keratinized mucosa or attached gingiva, problems with alveolar mucosa are not part of this operational area. If the bulge of an impacted canine is obvious from the palatal aspect, the cuspid tooth should be located superficially and accessible after soft tissue removal plus removal of covering bone. The patient shown in Figure 8, had no canine bulge on the left side on facial aspect (top row-left and center slides) but it was seen on the palatal aspect clinically (top row-right slide) and also in CBCT (bottom- left and center). Uncovering the tooth and bonding through a small window can be hectic using a scalpel a palatal flap may help in achievement an isolated and dry environment for the bonding and open or close eruption technique. Again sufficient bone removal is recommended without damage to the tooth root because PDL is the interface for tooth movement and the enamel of the crown has no potential for participating in bone remodeling and consequent tooth movement. Absolute anchorage was used for eruption of

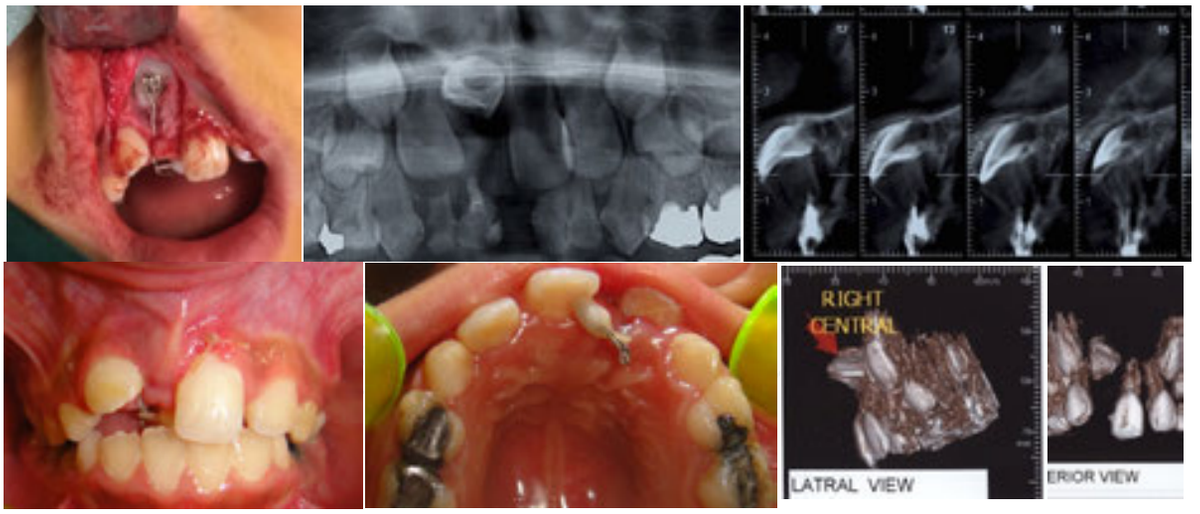

Figure 7. Upper right central incisor is positioned horizontally. An apically positioned flap is not indicated in the present situation and a closed eruption surgical approach may be used. Thin overlying bone can be removed with a periosteal elevator instead of rotary instrument (burs) and bonding performed in an isolated dry environment (top row). After wound healing, tooth 11 can be pulled towards the dental arch by means of absolute anchorage (mini-screws) or after bonding upper dental arch (continuous wire). In this case, an orthodontic attachment was bonded in the lingual fossa of tooth 11 and ligature wire was placed out of the flap for biomechanical extrusive forces (bottom row).

tooth #23 by means of Seifi Twin Screws (STS) for protecting other teeth from early unwanted orthodontic forces (Figure 8).

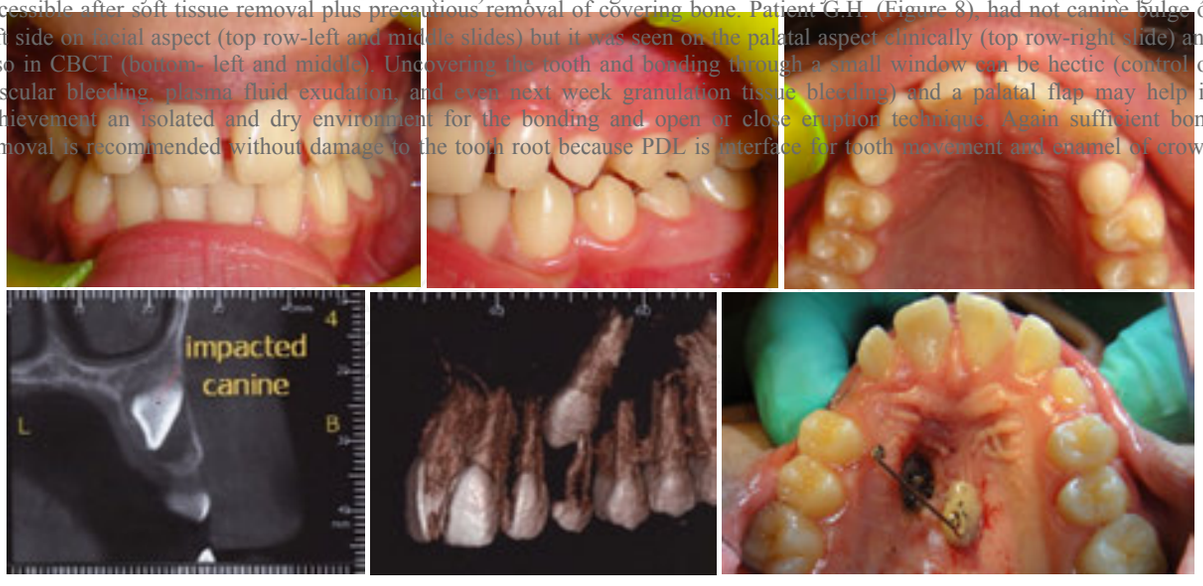

Figure 8. Patient with an impacted tooth #23 underwent a surgical uncovering of a palatal left canine (mirror image after surgery-bottom right). An absolute anchorage by combination of two miniscrews and a cantilever helical loop (Seifi Twin Screws/STS) was used for forced eruption or extrusion of impacted canine without exerting unwanted orthodontic force to the adjacent teeth. Miniscrews were covered by composites for better performance of springs and sustained stability.

4- Selection of the appropriate (efficient) biomechanical approach

After selection of proper approach to reach the impacted tooth, an appropriate biomechanical approach should be selected. A proper biomechanic system is capable of protecting periodontium and avoiding any unwanted tooth movement or root damage of the adjacent teeth.

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5. Selection of the appropriate (effective) biomechanical approach

After selection of the proper approach to reach the impacted tooth, an appropriate biomechanical approach should be selected. A proper biomechanical system is capable of protecting periodontium and avoiding any unwanted tooth movement or root damage of the adjacent teeth.

a. Anchorage preparation (Direct vs. Indirect)

In contrast to dental implants, orthodontic miniscrews are loaded immediately, and most authors suggest the use of light forces early on.[12] Only a few studies, mostly on animals, have dealt with the investigation of tissue reaction to immediate loading of miniscrew implants. Miniscrew implants can be immediate loaded (there is no need for a waiting period for osseointegration, in contrast to orthodontic implants), reducing the total treatment time. There is no need for complicated clinical and laboratory procedures (i.e., fabrication of acrylic splints by taking imprints with additional implant copying systems to accurately transfer the implant position to cast models) to facilitate safe and precise implant insertion.[13]

Direct anchorage screws are useful when prognosis of the eruption (impacted tooth) is questionable. If the impacted tooth is ankylosed, by applying force from a continuous arch, the dental arch could be deflected towards the ankylosed tooth (sometimes creating open bites); but an absolute anchorage could be a valuable tool to determine the sensitive stage of tooth eruption without endangering the adjacent anchored teeth (Figure 8). Direct anchorage can be used for anterior retraction in protrusion cases or non-extraction treatment of the Class III malocclusions (retraction of lower anterior sextant) and cases who have midline shift toward previous extraction sites (Figure 9).

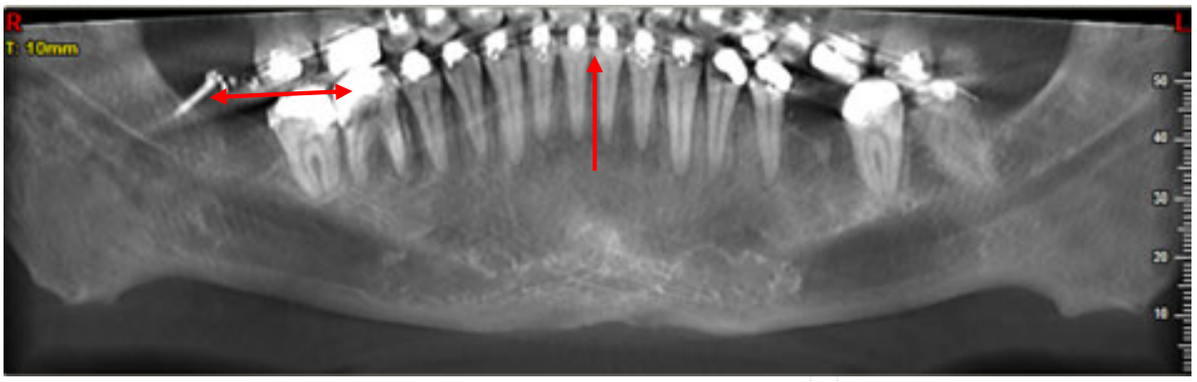
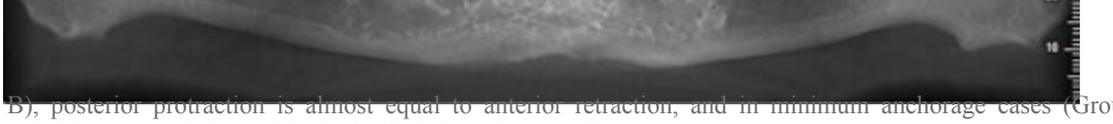


Figure 9. Patient M.T. had Class III open bite with midline deviation toward left side, a prvious extraction site. A miniscrew was inserted in retromolar area of right side for midline correction and meanwhile retraction of anterior teeth to correct class III relationship and establishment of proper overjet and overbite.

Figure 9. Patient with Class III open bite with midline deviation towards the left side, a prvious extraction site. A miniscrew was inserted in the right retromolar area for midline correction ; meanwhile retraction of anterior teeth to correct class III relationship and establishment of proper overjet and overbite was done.

Figure 10. Transpalatal arch (TPA) has served as indirect anchorage (contributing role of root surface area of upper first molars) in addition to a full size rectangulet wire that resist against reactive forces produced by traction force on the impacted upper right canine.



cases (Group B), posterior protraction is almost equal to anterior retraction, and in minimum anchorage cases (Group C), posterior protraction is

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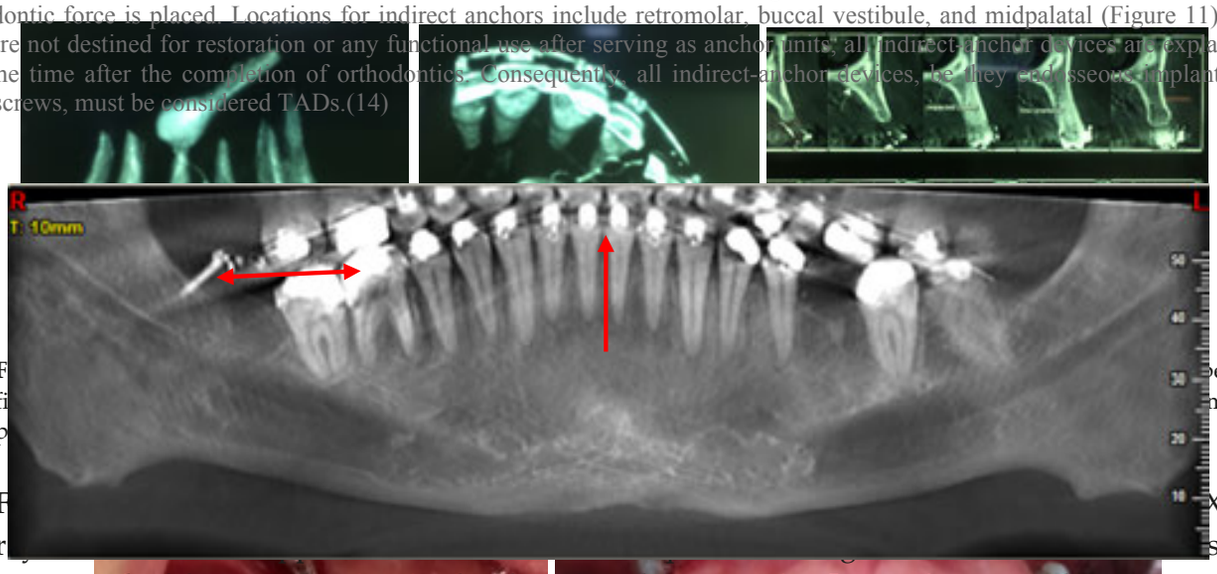
Indirect anchorage miniscrew stabilizes dental units, which in turn serve as the anchor units, and opens absolute anchor possibilities that can be established more flexibly than direct-anchor setups. Indirect-anchor setups will entail an implant, or TAD, placed in a non-dental location, which is then used to stabilize teeth, rendering them as indirect absolute anchors, on which orthodontic force is placed. Locations for indirect anchors include retromolar, buccal vestibule, and midpalatal (Figure 11). As they are not destined for restoration or any functional use after serving as anchor units, all indirect-anchor devices are explanted at some time after the completion of orthodontics. Consequently, all indirect-anchor devices, be they endosseous implants or mini-screws, must be considered TADs.(14)



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are sequel of force dispersion in the dental anchorage units. In maximum anchorage cases (Group A), ar area of right sident of posteriortion and protraction) should be less thato co% of the extraction site. In moderate anchorage cases (Group B), posterior protraction is almost equal to anterior retraction, and in minimum anchorage cases (Group C), posterior protraction is

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Figure 10. Transpalatal arch (TPA) has served as indirect anchorage (contributing to the loss of anchorage of upper first molars) in addition to a full size rectangulet wire that resist against reactive forces produced by traction force on the impacted upper right canine.

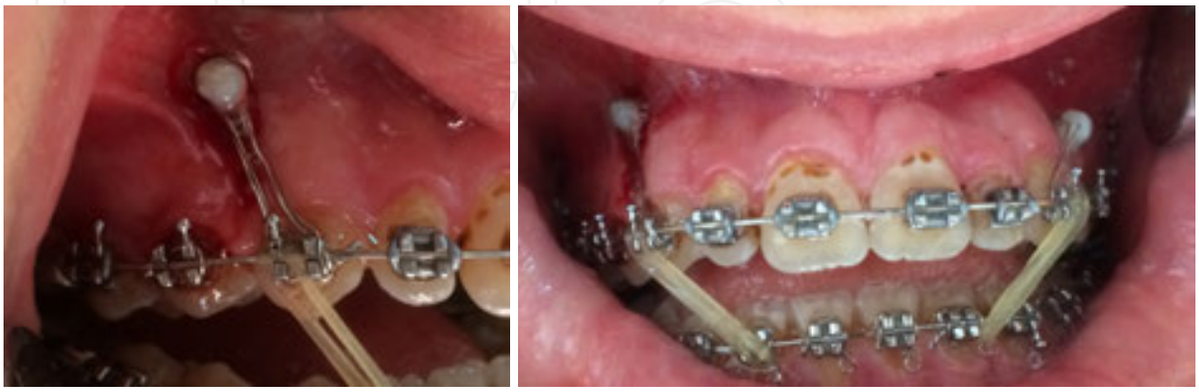

Figure 11. Miniscrews as an indirect anchorage resist against vertical pull of elastics for open bite closure. In the present condition eruption of lower anterior teeth has a major role for establishment of proper overbite. Vertical movement of the maxillary dentition is controlled by ligating both upper canines to miniscrews as indirect anchorage.

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b. Force application

After anchorage preparation, a pivotal phase of treatment begins i.e. force application for eruption of the impacted tooth into the dental arch. Any root damage to the impacted tooth is not acceptable e.g. ligating ligature wire around the cervical part of the tooth may destroy PDL and have a deleterious effect on periodontal health of the future leveled/aligned tooth. In addition, the author does not prefer enamel drilling for canine traction (EDCT) over accessory bonding for canine traction (ABCT) i.e. bonding orthodontic attachment for loading because of its inherent characteristics in enamel destruction. A clean, etched surface of enamel is a prerequisite for successful bonding but before force application, a recheck of bonded attachment by manual traction is a prerequisite for wound closure.

Description of tooth movement for an impacted tooth is intricate and difficult. Only 3-dimensional analysis that contains information on both rotation and translation of the tooth movement has potential to evaluate and explain the nature of the exact movement. However, coordinate systems are used in orthodontics for better understanding of clinicians. Application of force to the center of resistance of a rigid body can produce translation without rotation. If the vector of the force is out of the center of resistance (C_{Res}), according to its distance to the C_{Res} it can produce a moment of the force (M_F) with an expression of rotation for free-bodies or rotation tendency for teeth. In Figure 12, a 100 gram force plus 1000 g mm of moment equals the 100 gram force applied to the bracket with 10 mm distance. By addition of counterbalancing moment (M_C) i.e. insertion of rectangular archwire in the bracket slot and its engagement to the walls, the bracket system will act like the system in the green box of Figure 12 (the green box is hypothetical) and depending on the proportion of M_C/M_F, a controlled tipping ($0<M_C/M_F<1$), translation or bodily movement ($M_C/M_F=1$), and torque ($M_C/M_F>1$) can be produced.

The relationship between the orthodontic force and counterbalancing moment is also expressed in the "moment to force ratio" or M/F ratio. M/F ratio 1 to 7 would produce controlled tipping, ratios of 8 to 10 (according to root length) produce bodily movement, and ratios greater than root length produce root torque movement.

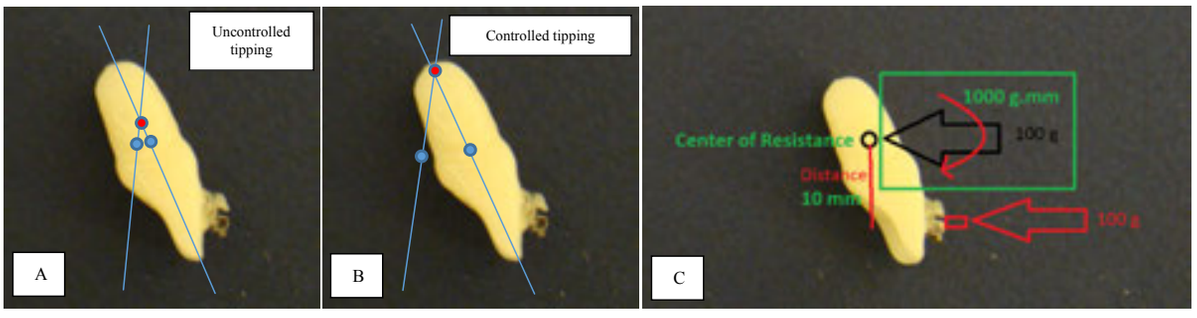

Figure 12. Application of force to the bracket without any tools to exert moment (like round wire in bracket or labial bow in removable appliances) produce a type of "uncontrolled tipping" movement (slide A). In this type of movement, the center of rotation (red circle) is near the center of resistance (blue circle). The similar or equivalent force system can be produced by exerting force (100 g) plus moment (100x10=1000 g.mm) to the center of resistance (green box- slide C). If 100 g force is applied to bracket (slide A) and a counterbalancing moment (M_C) is produced by rectangular wire (slide C) but less than 1000 g.mm; it can move the center of rotation to near apical area and create a type of "controlled tipping" (slide B) type of movement.

The correct M/F ratio should be obtained for bringing the impacted tooth to the dental arch but it is important to maintain the ratio for a constant center of rotation. By using rectangular loop (R-loop) in a cantilever spring, load-deflection rate will be decreased i.e. make the spring more flexible (relative to straight wire), and the configuration of the spring leads to a better maintenance of M/F ratio for a constant center of rotation. Segmented R-loop has long range of action with minimal force decrease during tooth movement and acceptable control of force magnitude. If the spring is distorted by the patient, cantilever spring do not fail safely, and it can significantly move the tooth in an unwanted direction (Figure 13).

Treating a clinical case of a maxillary canine in infralabioversion by means of the straight archwire technique used to level the tooth is a harmful procedure for adjacent teeth. Canine extrusion would occur regardless of the type of bracket, whether conventional or self-ligating, however, it would be followed by undesired intrusion and moments on the lateral incisor and first premolar (figure 14). Many authors believe that these side effects would be solved with intermaxillary rubber bands, arch bends

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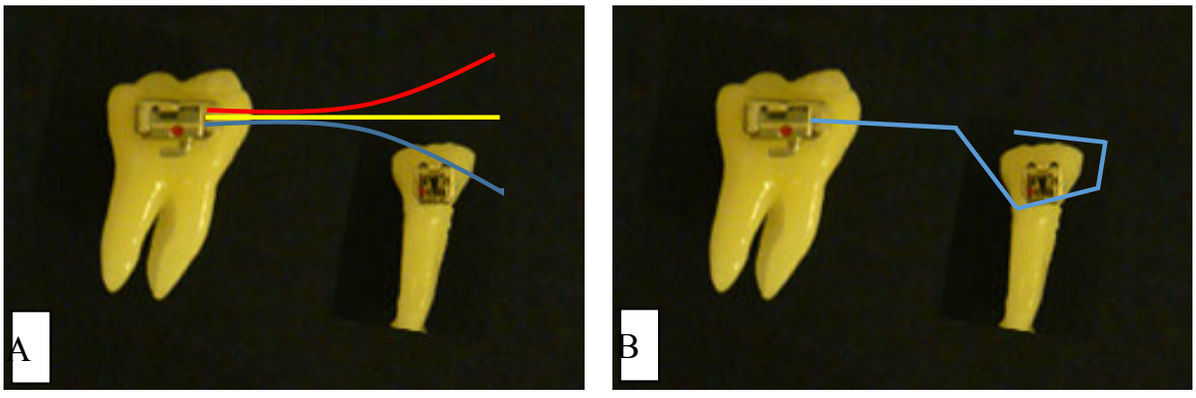

Figure 13: A straight wire is used in (A) to erupt the bicuspid. When the wire is bent (blue line) and engaged in the bracket, the root apex tends to go to distal, in the next yellow line position, the root is upright and moment drops off, and in red line position; roots tends to go to the mesial while the crown is depressed. With this configuration, several centers of rotation exist and constancy of the moment to force ratio is affected (inconsistent force system). Slide B demonstrates preactivated rectangular loop (R-loop) which provides constant control of M/F ratio. The R-loop is made from 0.018x0.025 inch Stainless Steel or 0.017x0.025 inch Titanium Molybdenum Alloy (TMA).

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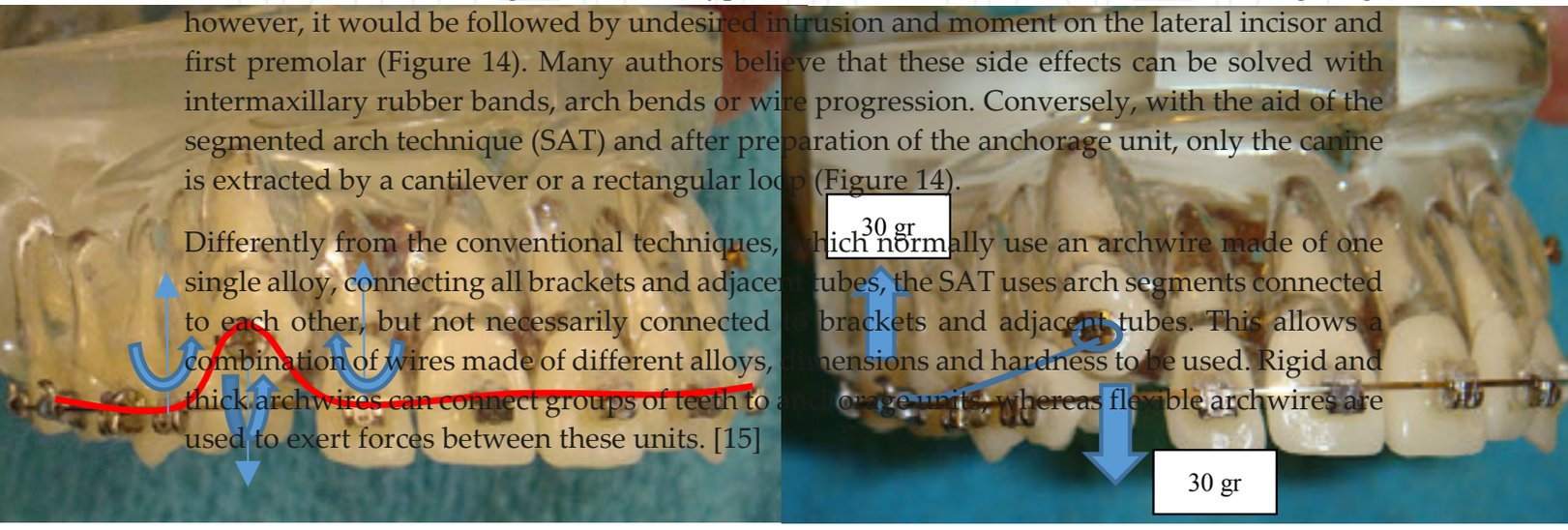
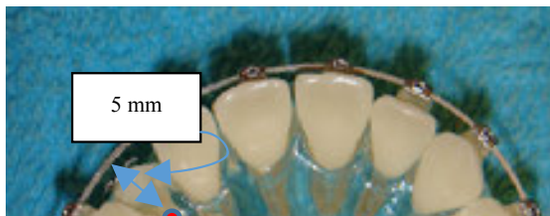
Differently from the conventional techniques, which normally use an archwire made of one single alloy, connecting all brackets and adjacent tubes, the SAT uses arch segments connected to each other, but not necessarily connected to brackets and adjacent tubes. This allows a combination of wires made of different alloys, dimensions and hardness to be used. Rigid and thick archwires can connect groups of teeth to anchorage units, whereas flexible archwires are used to exert forces between these units. [15]





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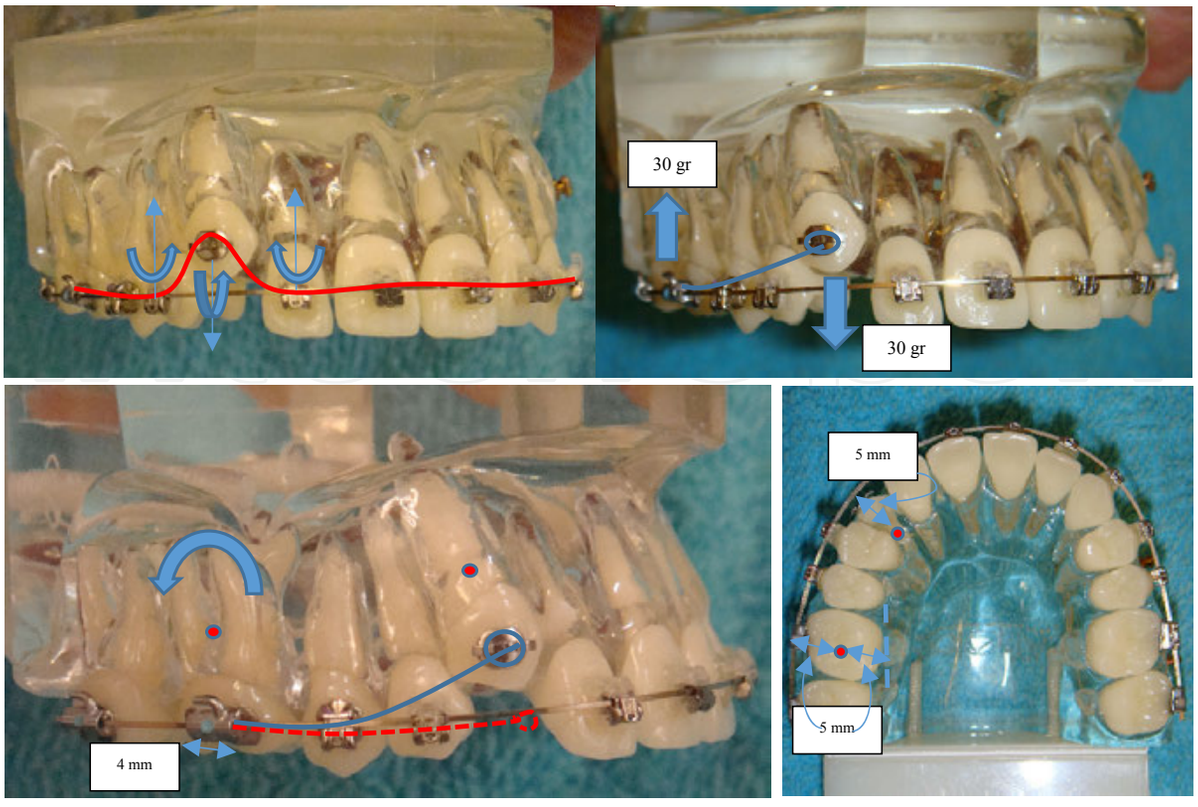

Figure 14. Top-left) Continuous archwire (NiTi or CuNiTi) or straight archwire technique can be used to level the impacted canine/high buccal canine (infralabioversion canine) but canine extrusion would be followed by intrusive force and positive and negative moments on first premolar and lateral incisor. A lingual moment is created for the upper canine that will lead it to the dental arch. Top-right) with the cantilever mechanics or segmented arch technique (SAT), a cantilever rectangular spring is inserted into a rectangular tube and tied to one point on the other side to produce "determinate one-couple system". Bottom-left) Sectional cantilever spring is used to extrude the impacted canine (force 30 grams, and distance between canine and first molar, presumably, about 20 mm). Extrusive force on canine (30 grams) will produce 30 gram intrusive force on upper first molar plus 600 g mm moment (M=Fxd=30x20=600) to create distal root movement (blue arrow). The moment may be created by a couple (molar tube, presumably, 4 mm in length) with 150 grams force (600/4=150g) upward on the mesial end of the tube and 150 grams downwards on the distal end. Bottom-right) the abovementioned force system from the occlusal view. Consider the moment created by the rectangular archwire in molar tube (torque) and moment on canine. If center of resistance of the canine tooth is, presumably, about 5 mm lingual to the bonded button on the crown, a 150 g mm (30x5=150g.mm) moment rotates the tooth lingually. At the first molar, if the center of resistance is 5 mm lingual to the tube, a 30 g intrusive force can create 150 g mm moment to rotate it buccally. If the center of resistance of the impacted canine is, presumably, 10 mm palatal to the buccal surface of the first molar, activation of spring to tie to the canine, can twist it and create 300 g mm (30x10=300g mm) moment to rotate the molar crown palatally. The result at the molar is a net 150 g mm (300 g mm palatal – 150 g mm buccal =150 g mm palatal) palatal crown torque. (Bracket type and existence of continuous archwire of the model are not related to the biomechanical explanations.)

5.1. Biomechanical alternatives for forced tooth eruption

The orthodontist should avoid mechanics that draw the tooth labially, which could produce a bony dehiscence and accelerated migration of the labial gingival margin, resulting in labial recession. A "Ballista" loop is a simple, convenient, unobtrusive method of applying a vertical vector of force to a labially impacted tooth to erupt the crown into the center of the alveolus. When the canine crown is displaced mesially and lies over the root of the permanent lateral

incisor, an apically positioned flap is the appropriate surgical uncovering technique. Exposure of the crown facilitates attachment of an elastomeric chain directed toward the center of the edentulous alveolar ridge to gradually guide the canine crown into the dental arch. [16] A "Vertical spring" bent into 0.14 inch stainless steel wire that faces downward before activation is another alternative. It can be activated by pushing the vertical legs toward the impacted canine. This kind of round wire has the benefit of increased length and springiness but needs some kind of anti-rotation bent for avoiding rotation of round wire inside bracket slot that neutralizes the activity of the spring. Another alternative is an "Overlaid Auxiliary NiTi wire" on the rectangular stabilizing arch. These auxiliary arch wires are very efficient to bring an impacted tooth into dental arch. "Cantilever springs" can be used, either soldered to a heavy base arch or from auxiliary tube on the first molar. Some have used headgear tube plus an anti-rotation bend on wire and a helix around main arch wire for forced eruption of impacted teeth.

5.2. Molar uprighting in impacted cases

A dental arch with aligned teeth and heavy main archwire can serve as an anchorage unit to be used for uprighting posterior second or third molar teeth by a NiTi or sectional Stainless Steel wire incorporating loops e.g. T-loop. Absolute anchorages i.e. miniscrews or titanium miniplates are other alternatives for distalizing or uprighting impacted molar teeth (Figure 15).

Figure 15. T-loops have efficient control on angulation and torque of an inclined tooth (left). An alternative to absolute anchorage can help in uprighting the tilted impacted second or third molars without endangering other teeth as anchorage units that may be affected with orthodontic force and tooth movement or root resorption.

Molar uprighting is generally associated with extrusion of antagonist teeth, reduction in edentulous space, bone dehiscence in the mesial surface of tipped molars, gingival recession of tipped molars, early contact in centric relation and occlusal interference on excursion of the mandible. With regard to integrated planning, clinicians must decide whether the tooth subject to uprighting will undergo movement for space closure, opening of space for prosthetic rehabilitation or implant placement. Mesial movement of molars may be rendered difficult due to the following: alveolar bone resorption resulting from tooth loss, which causes the molar mesial bone to become too thin; unfavorable root morphology for movement of lower molars; greater mandibular bone density in relation to the maxilla; and thin buccolingual bone thickness from distal to mesial in the mandibular arch. Using straight wires to upright tipped

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molars is considered unfeasible, given that, in these cases, there is a strong tendency towards extrusion of molars, especially due to the short distance between brackets. Additionally, incorporating a T-loop spring into the arch will lead to extrusion of premolars. A cantilever, extended up to the anterior region, may be used to reduce the effects of extrusion on molars. Researchers have proved a moment of 1200 gf.mm to be appropriate for molar uprighting. Should a 30-mm cantilever be used, an activation of 40 gf is enough for molar uprighting, in which case 40 gf corresponds to intrusive forces in the anterior region and extrusive forces in the region of molar teeth. Mesocephalic or brachycephalic patients are able to eliminate or reduce this effect of extrusion by their own muscular pattern. [15, 17]

6. Alignment/ Leveling/Torque/Angulation (ALTA) corrections

The root apices are located in the apical portion of the jaws and malposition almost always develops as the eruption paths of teeth are deflected; for impacted teeth the problem is more complicated and both apex and crown are usually misplaced. ALTA corrections have been considered for the time that impacted tooth has been brought near to the dental arch. Light and continuous force is recommended for the beginning of the treatment i.e. "Alignment", through tipping movement for impacted teeth in facio-lingual direction. As a general rule, heavy wires should be avoided at this stage. A minimum of 0.004 inch clearance is needed for sliding mechanics, in other words, in 0.018 slot an archwire with 0.014 inch stainless steel can be accepted for sliding but for severe crowding or malposition situation, more length of wire in the form of loop or helices should be incorporated. Although resilient wire with rectangular shape like A-NiTi or CuNiTi (Damon system) could be used, but because they produce unwanted root movement, possible root resorption, and possible delay in alignment progression, rectangular resilient wires are not advisable. Wires should have excellent strength and springiness, long range of action and low load deflection rate. NiTi wires are springier and stronger (in small section) than beta-titanium (TMA), for these reasons, A-NiTi and CuNiTi wires are recommended for initial stages of aligning.

In addition to alignment, impacted teeth should be "Leveled" in occluso-gingival direction. Leveling can be obtained by absolute intrusion or by relative intrusion and sometimes by differential elongation or extrusion of teeth. Utility arches e.g. 2x4 appliance, reverse curve for lower arch, intrusion arch and combination of sectional wires, segmented arches and titanium miniscrews are used for leveling the dental arch.

After establishment of proper alignment and leveling, two other crown position characteristics should be achieved i.e. "Torque" and "Angulation". Torque is in facio-lingual direction and usually involves root movement and moment (increased M/F ratio) is needed for its correction. Angulation is related to mesio-distal characteristics of crown positioning and like the amount of torque degree, is considered in bracket prescription in straight wire appliances (SWA). Wire bending like what is performed in "Standard Edgewise" for finishing and establishment of correct torque and angulation, is needed for severe impacted cases for obtaining the proper ALTA correction and accepted occlusion (according to ABO scores).

7. Conclusion

Bone-impacted canines of the hard palatal are more likely to respond to surgical exposure and orthodontic management if angulation to midline is less than 45 degrees on the OPG; there is no root anomaly found on OPG, periapical (PA), and maxillary occlusal (MO) radiographs; and overlap of the adjacent lateral incisor root (OALIR) by the canine crown is nonexistent or less than grade 2 (half the root) on the OPG.[18] Researchers have tried to predict impaction of a maxillary canine using geometric measurements made on panoramic radiographs. Diagnosis of an outcome can be performed cross-sectionally, however; for prediction, two separate prospective data sets should be used. [19]

Deimpaction of the impacted teeth can be accelerated by means of thick soft tissue removal with laser application. Laser-assisted surgical removal of the fibrous tissue over erupting premolars (DTE) with appropriate irradiation parameters appears to be a promising adjunct to orthodontic treatment for bringing them to the aligned and leveled dental arch.[20] Orthodontic tooth movement and root resorption of impacted teeth can be influenced by laser [21] and administration of different drugs.[22,23]

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References

[1] CA C. A Method of ascertaining, the Relative Position of Unerupted Proc R Soc Med 1910;3((Odontol Sect)):87-90.

[2] Jacobs SG. Radiographic localization of unerupted teeth: further findings about the vertical tube shift method and other localization techniques. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics. 2000;118(4):439-47.

[3] Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. The British journal of radiology. 2009;82(973):35-40.

[4] Trobe JD KJ. Cost-benefit analysis in screening. Unexplained visual loss.. Surv Ophthalmol 28(3):189-93.

[5] Bahreman A. Early-age orthodontic Treatment: Quintessence Publishing Co, Inc; 2013.

[6] Stewart JA, Heo G, Glover KE, Williamson PC, Lam EW, Major PW. Factors that relate to treatment duration for patients with palatally impacted maxillary canines. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics. 2001;119(3):216-25.

[7] Zuccati G, Ghobadlu J, Nieri M, Clauser C. Factors associated with the duration of forced eruption of impacted maxillary canines: a retrospective study. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics. 2006;130(3):349-56.

[8] Ericson S KJ. Resorption of maxillary lateral incisors caused by ectopic eruption of the canines. A clinical and radiographic analysis of predisposing factors. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics.94(6):503-13.

[9] Pitt S, Hamdan A, Rock P. A treatment difficulty index for unerupted maxillary canines. European journal of orthodontics. 2006;28(2):141-4.

[10] Warford JH, Grandhi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. American Journal of Orthodontics and Dentofacial Orthopedics. 2003;124(6):651-5.

[11] Kau CH, Pan P, Gallerano RL, English JD. A novel 3D classification system for canine impactions--the KPG index. The international journal of medical robotics + computer assisted surgery : MRCAS. 2009;5(3):291-6.

[12] Melsen B, Verna C. Miniscrew implants: The Aarhus anchorage system. Seminars in Orthodontics. 2005;11(1):24-31.

[13] Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2007;103(5):e6-15.

[14] Celenza F. Implant Interactions with Orthodontics. Journal of Evidence Based Dental Practice. 2012;12(3):192-201.

[15] Caldas SG, Ribeiro AA, Simplício H, Machado AW. Segmented arch or continuous arch technique? A rational approach. Dental Press J Orthod. 2014 Mar-Apr;19(2): 126-41.

[16] Kokich VG. Surgical and orthodontic management of impacted maxillary canines. Am J Orthod Dentofacial Orthop. 2004 Sep;126(3):278-83.

[17] Romeo DA, Burstone CJ. Tip-back mechanics. Am J Orthod. 1977 Oct;72(4):414-21.

[18] Motamedi MH, Tabatabaie FA, Navi F, Shafeie HA, Fard BK, Hayati Z. Assessment of radiographic factors affecting surgical exposure and orthodontic alignment of impacted canines of the palate: a 15-year retrospective study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009 Jun;107(6):772-5. doi:10.1016/j.tripleo.2008.12.022.

[19] Sabour S, Vahid Dastjerdi E. Early prediction of maxillary canine impaction from panoramic radiographs. Am J Orthod Dentofacial Orthop. 2012 Oct;142(4):428; author reply 428-9. doi: 10.1016/j.ajodo.2012.08.010.

[20] Seifi M, Vahid-Dastjerdi E, Ameli N, Badiee MR, Younessian F., Amdjadi P. The 808 nm Laser-Assisted Surgery as an Adjunct to Orthodontic Treatment of Delayed Tooth Eruption: J Lasers Med Sci 2013; 4(2):70-4

[21] Seifi M, Atri F, Yazdani MM. Effects of low-level laser therapy on orthodontic tooth movement and root resorption after artificial socket preservation. Dent Res J (Isfahan). 2014 Jan;11(1):61-6.

[22] Seifi M, Eslami B, Saffar AS. The effect of prostaglandin E2 and calcium gluconate on orthodontic tooth movement and root resorption in rats. Eur J Orthod. 2003 Apr; 25(2):199-204.

[23] Seifi M, Badiee MR, Abdolazimi Z, Amdjadi P. Effect of basic fibroblast growth factor on orthodontic tooth movement in rats. Cell J. 2013 Fall;15(3):230-7. Epub 2013 Aug 24.