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Biomechanics of Tooth-Movement: Current Look at Orthodontic Fundamental

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1. Introduction

Numerous methods of efficient orthodontic tooth-movement have been described in the literature for over 100 years, since Edward Hartley Angle had introduced foundations of malocclusion treatment (fig. 1). In such long term, different treatment philosophies have been permanently encountering beginning from Tweed[1] and his extraction concept versus

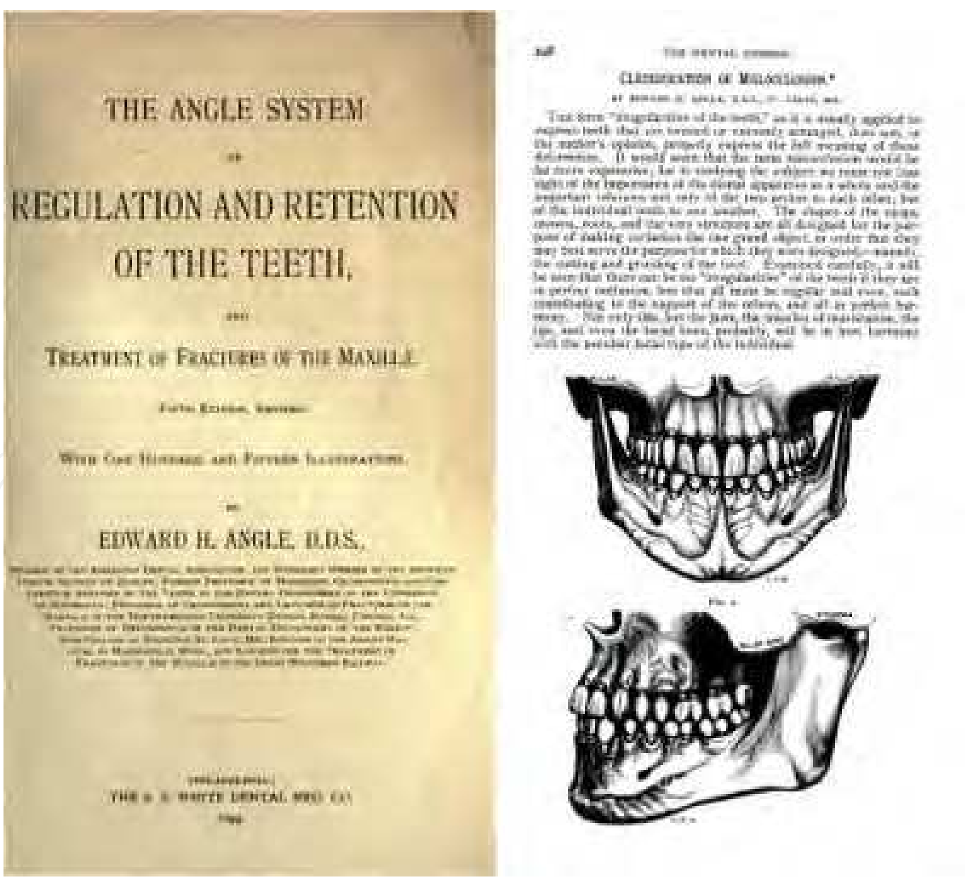


Fig. 1. Beginning of former century: philosophy proposed by the father of Orthodontic School, E.H. Angle

orthopedic functional expansion approach of acknowledged masters, such as: Andresen, Bimler, Klammt, Fränkel, Stockfish or Balters[2] (fig. 2a, b). Numerous appliances and techniques have been designed to accomplish treatment goals assumed by advocates and followers of both schools, especially challenging in adults who more and more frequently seek orthodontic care. Evidence based efficiency of sliding mechanics[3] and segmented technique[4-11] mostly related to the space closure (fig. 3a-c), maxillary enlargement in different skeletal configurations: class III[12-25] or II[26-28] prior to mandibular advancement or distalization of maxilla[29-46] are approaches of choice in non-extraction protocol.

(a) (b)

Fig. 2. Balters' bionator in situ: a) en face view, b) right side

(a) (b) (c)

Fig. 3. Space closure with T-loop segmented archwire: a) initial occlusion, right side, b) T-loop in situ, c) final occlusion, right side

Independently on the treatment plan calling either for reduction of teeth number or dental arch expansion and despite modern and sophisticated orthodontic appliance or technique, even the most currently performed dental movements base on Newton's 3rd law established already in 1687: *to every action there is always opposed an equal reaction or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts*[47]. Such fundamental enlightened orthodontist - beyond the shadow of the doubt - that any teeth-anchored desired movement produced the undesired one and the latter was to be carefully predicted thus fully controlled (fig. 4a, b). Meticulous evaluation of moments and forces resulting from planned tooth displacement[48-51], unavoidable for "orthodontic-driven" and efficient tooth-movement, initiated development of biomechanics: pure physics transferred into the oral cavity (fig. 5a-c, 6a-c). The concept resulted in deliberate anchorage reinforcement: increase of resistance of fulcrum located either in on teeth or skeletal structures[52].

Anchorage may be reinforced utilizing: a) extra-oral skeletal structures, b) teeth and intra-oral skeletal structures.

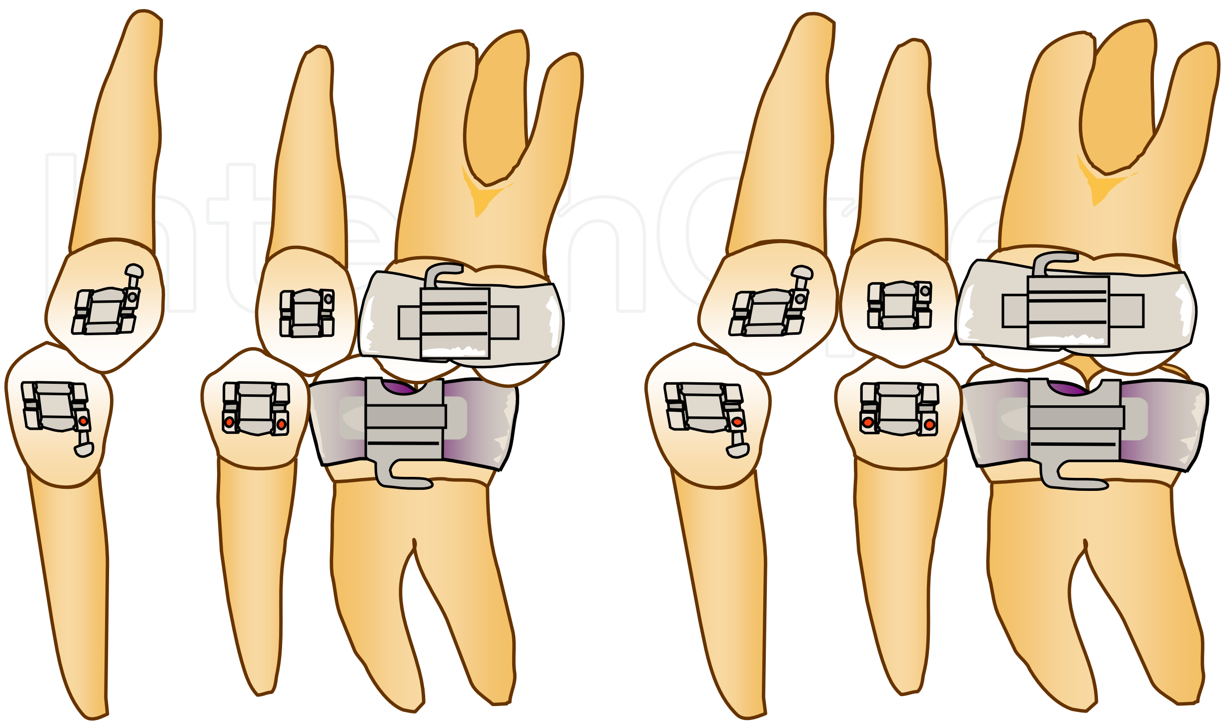


Fig. 4. Anchorage loss during canine retraction: a) initially - class I on both sides b) finally – cusp to cusp relationship due to mesial displacement of upper molars

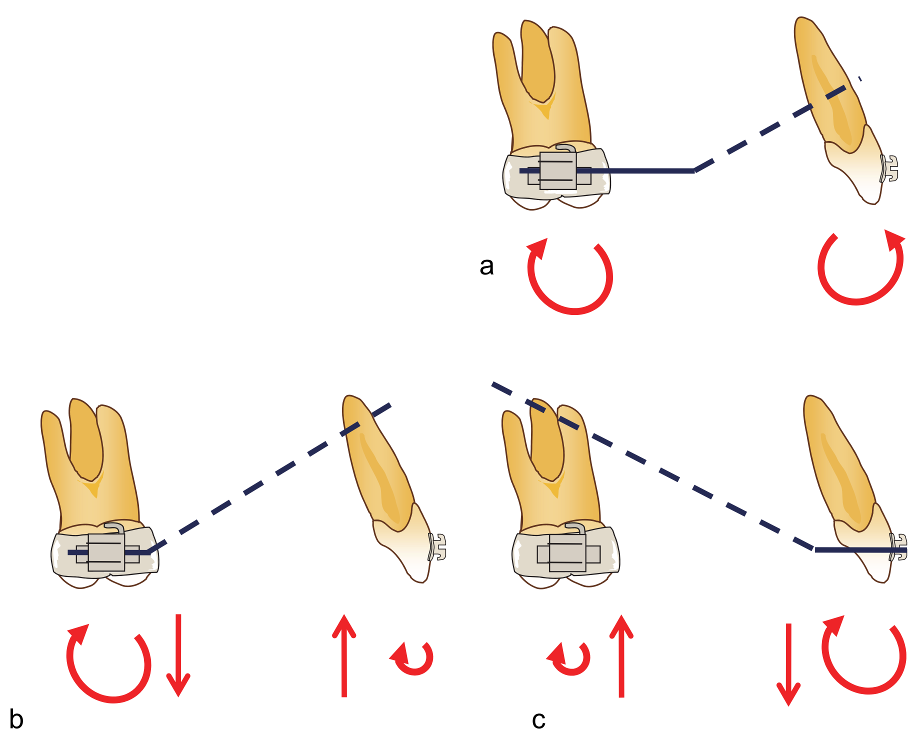


Fig. 5. Force vectors and moments displacing teeth in sagittal-vertical plane, depending on localization of the archwire bending between canine and 1st molar (provided there are no brackets on premolars): a) middle of the distance, b) close to 1st molar, c) close to a canine

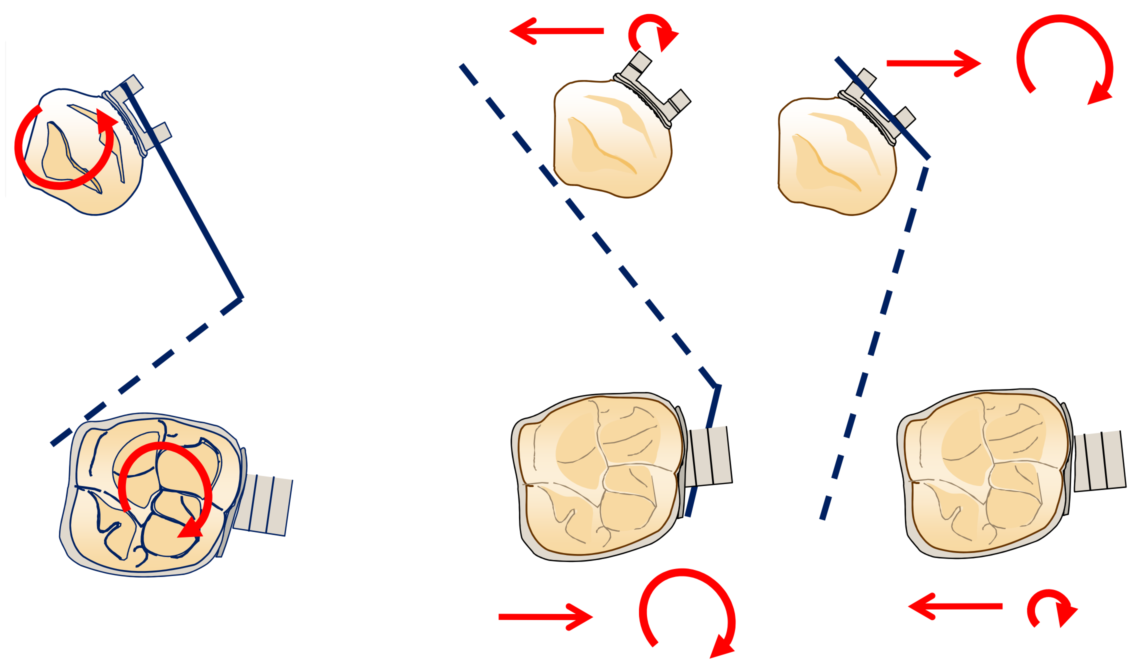


Fig. 6. Force vectors and moments displacing teeth in occlusal plane, depending on localization of the archwire bending between canine and 1st molar (provided there are no brackets on premolars): a) middle of the distance, b) close to 1st molar, c) close to a canine

a. Extra-oral appliances

Headgear - known already in 19th century allows orthodontic reacting forces pass through cranium and back bone: immobile structures, thus absolute anchorage is achieved. Position of external arms of the face bow dictates line force, in other words: enable precise prediction of the desired direction of tooth-movement[53] (fig. 7a-c). In order to adjust the line force, molar center of resistance must be established first. According to Schmuth et al.[54] such location may be easily predicted in several steps: 1) the face-bow, after adjustment of internal arms must lie flat on the surface, 2) reference points must be marked on external arms, 3 mm mesially to the ends of internal ones, 3) once the face-bow has been inserted in to the headgear tubes, next reference points must be marked 8 mm above the previous ones, on the patient's skin (fig. 8). Precisely designed headgear (fig. 9a-c) is mainly applied for correction of class II; nevertheless it may also be used for correction of class I with crowding in both jaws, in combination with fixed mechanics (fig. 10).

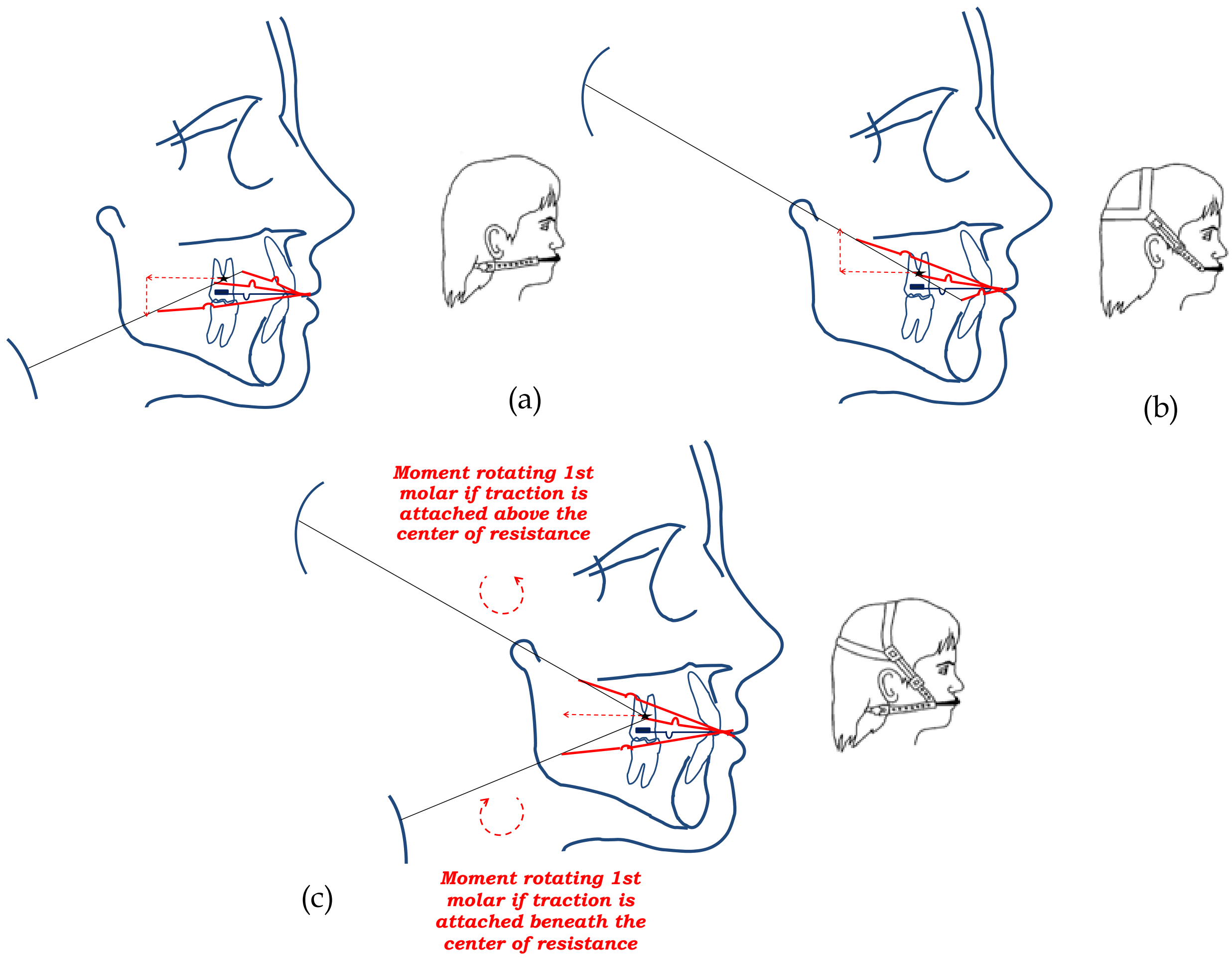


Fig. 7. Headgear - force vectors depending on position of external traction: a) low-pull, b) high-pull ; c) combi-pull; note that elimination of molar rotating moments depends on either the length as well as on angulation of face bow external arms

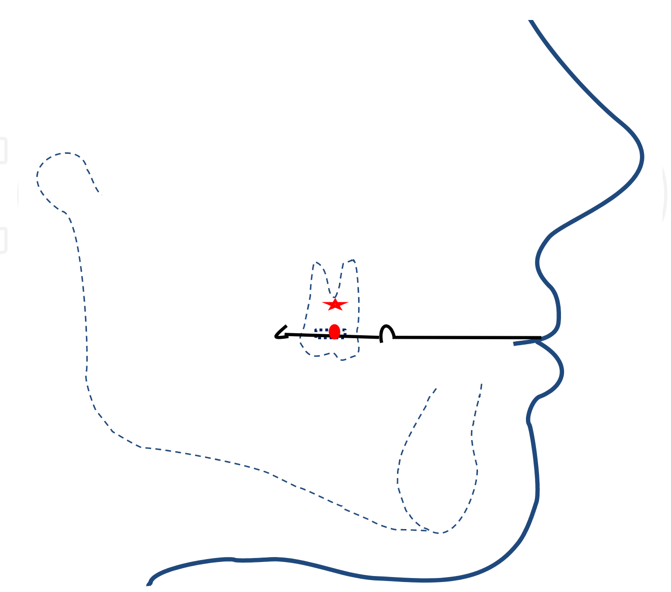


Fig. 8. Headgear adjustment: marking the center of molar resistance (asterisk) on patient's skin

(a) (b) (c)

Fig. 9. Low pull headgear adjusted for class II treatment: a) en face view: position of face bow: it does not lean against lips, b) lateral view - external arms of the face bow bent up, c) external arms of the face bow bent down; note the direction of force line (⟶) and moment (M) rotating molar.

Fig. 10. Headgear combined with fixed appliances: intermaxillary class III traction forces lower canine distally

(a) (b)

Fig. 11. Intrusion arch according to Burstone a) en face, in situ, b) connection of cantilever with front segment

Current mathematic calculations of forces couneracting reactive ones resulting from the front teeth movement are presented by Braun[55]. Burstone's intrusion arch (fig. 11a, b) while intruding upper incisors with the 50 g of force, simultaneously extrudes molars with the same force value. To prevent the latter phenomena, high-pull headgear is to be worn 8 hours per day. It is illustrated with the formula: F_1 x 8h = 50 g x 24h, where F_1 = 150 g is a vertical component of the force produced by high-pull traction (fig. 12). However net force

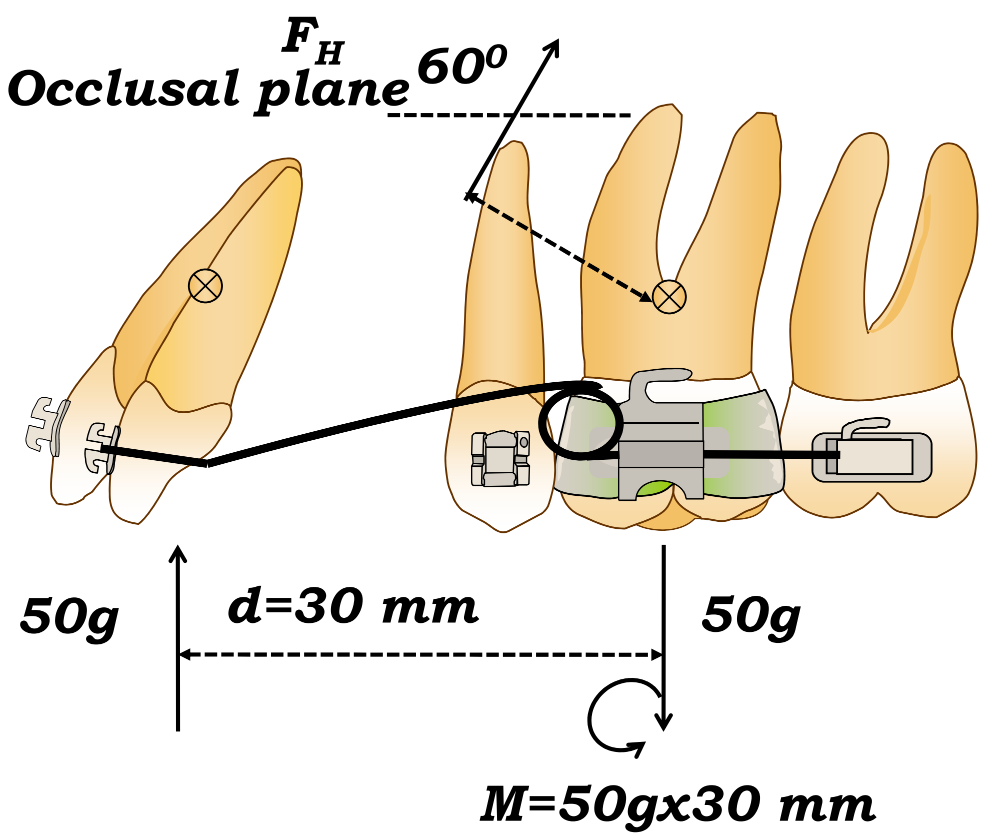


Fig. 12. Biomechanics of incisor intrusion with Burstone's cantilever. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

vector is inclined 60^0 to the occlusal plane, therefore net force value (F_H) equals: $F_H = F_1/\sin 60^0$ = 173 g. Furthermore, in order to compensate side effect of Burstone's cantilever - moment inclining molars distally - stripes of high-pull headgear must be attached at the certain distance (D) from the center of molar resistance, thus inclining molars mesially: 50 g x 24h x 30 = 173 g x 8h x D, so D = 26,01 mm. Another example: retraction of front teeth with the 200 g of force simultaneously displaces molars mesially (fig. 13). Horizontal force reinforcing anchorage (F_2) and originating from the low-pull headgear worn 10 hours per day equals 480 g (200 g x 24 h = F_2 x 10 h). Consequently, since the net force vectors of either high-pull as well as low-pull headgears are inclined to the occlusal plane, their efficient force values equal 627 g (480/cos 40^0) and 679 g (480 g/cos 45^0) respectively.

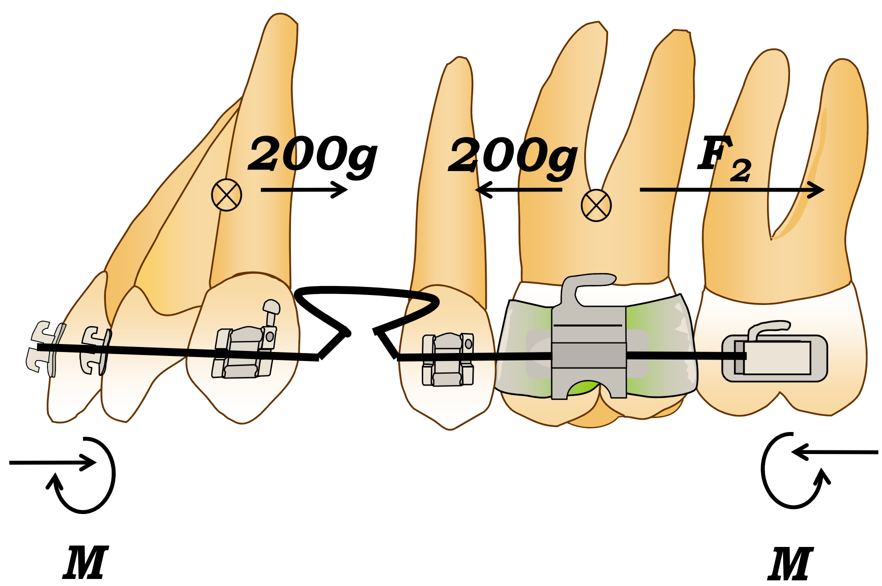


Fig. 13. Biomechanics of controlled space closure. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

Fig. 14. Face mask

Nevertheless, despite so precise calculations, biologic response is inadequate to the expected one. As reported by Melsen and Bosch[56] when an orthodontic force is applied to a tooth, the cells of periodontal ligaments are differentiated into active osteogenic and osteoclastic cells. As a result, both periodontal ligaments and the adjacent bone exhibit increased cellular activity facilitating tooth movement, therefore headgear - if worn intermittently - is incapable of efficient anchorage reinforcement.

Face mask applied in class III treatment as orthodontic and orthopedic traction (fig. 14) is anchored on a forehead and a chin. Since mandible is a moving structure, therewith its response is unpredictable in terms of mathematic calculations, although efficient clinically. Nevertheless, as anchorage control is also achieved intermittently, all the displacements are resultants of the desired movements and transient collapses.

b. Teeth anchored appliances

Teeth anchored appliances are generally the most popular ones widely used for anchorage reinforcement. Rapid maxillary expander (fig. 15) is an appliance designed to correct transverse discrepancy in class III cases. Nance button - mounted in maxilla and supporting class II correction with eg. repelling magnets[57], superelastic springs[58-60], jones-jig appliance[61-62], pendulum appliance introduced by Hilgers[63] (fig. 16a, b) or Keles slider®[64] (fig. 17) - utilizes hard palate, therefore its efficiency is highly dependent on palatal morphology[65] (fig. 18a, b).

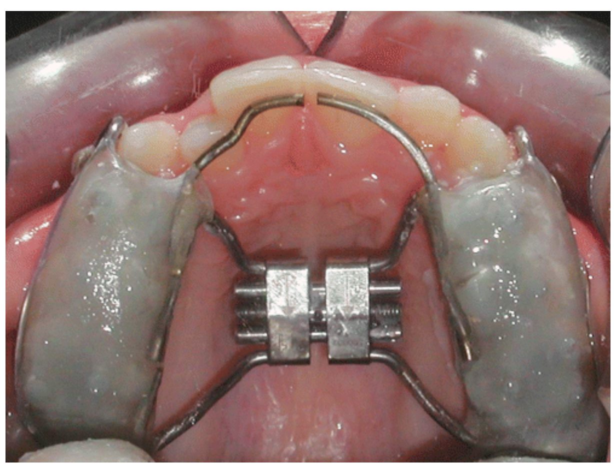


Fig. 15. Rapid maxillary expander

(a) (b)

Fig. 16. Pendulum appliance: a) inter-dental spaces gained after unilateral activation, b) final symmetric positionof upper molars

Fig. 17. Keles slider®. Source: Mavropoulos A, Sayinsu K, Allaf F, Kiliaridis S, Papadopoulos MA, Ozlem Keles AO. Noncompliance unilateral maxillary molar distalization. Angle Orthod 2006,3:382-7

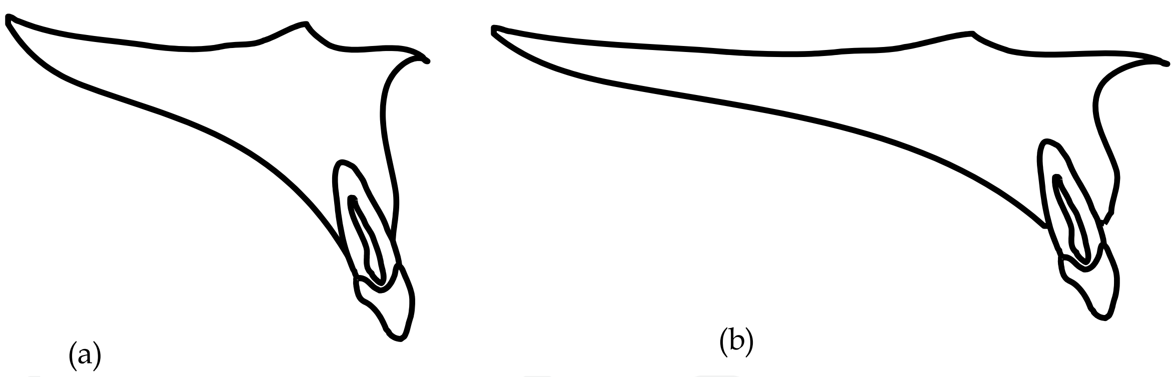
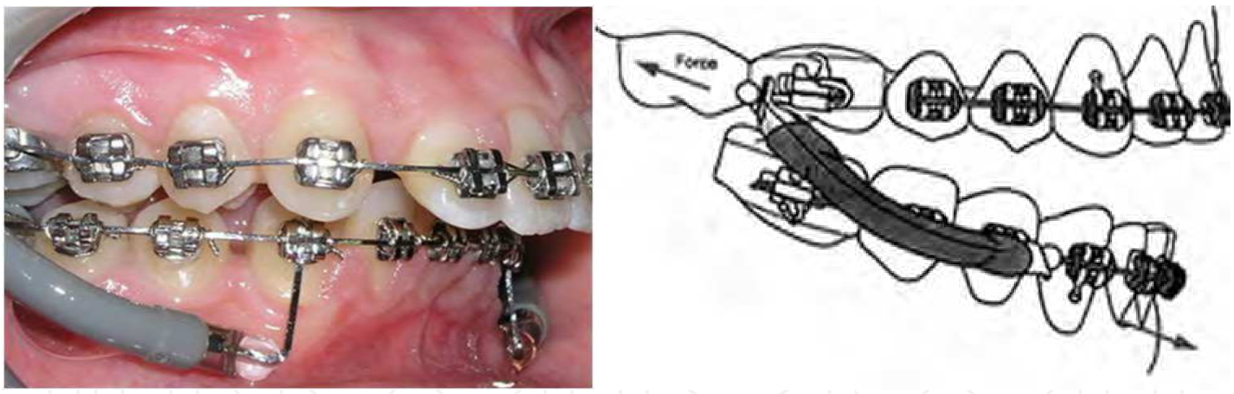


Fig. 18. Palatal morphology: a) steep vault and b) flat vaults, respectively favoring and incumbering Nance-button settling. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

On the other hand, bi-maxillary appliances such as Herbst hinge[66] , Carrière distalizer®[67], jasper-jumper[68] (fig. 19a, b), MALU (fig. 20) or Forsus® (Fig. 21a, b), designed for advancement of mandible in young adolescents with concave profile (fig. 22), are dependent on initial teeth-positions. In other terms, protrusion of lower incisors permits functional treatment of class II, since their further flaring is the adverse, unavoidable effect of mandibular forward displacement.



(a) (b)

Fig. 19. Jasper-jumper a) in situ, b) scheme of delivered force vectors. Source: Küçükkeleş N, Ilhan I, Orgun IA. Treatment efficiency in skeletal Class II patients treated with the jasper jumper. Angle Orthod 2007;77:449-56

Fig. 20. MALU

(a) (b)

Fig. 21. Forsus appliance in situ: a) during mouth opening, b) after mouth closure; note transient class III (over-correction of class II) evident on canines and molars

Fig. 22. Concave facial profile of young adolescent – indication for mandibular forward displacement

Evaluating appliances settled on the teeth it may be stated that their biomechanics bases on paradigm that larger overall surface of the roots composing anchor unit is resistant to the orthodontic forces displacing individual tooth (fig. 23). It sounds logic, however this concept is totally opposite to the very interesting one presented by Mulligan and well grounded in terms of biomechanics[69]. The author proved that the undesired molar mesialization during

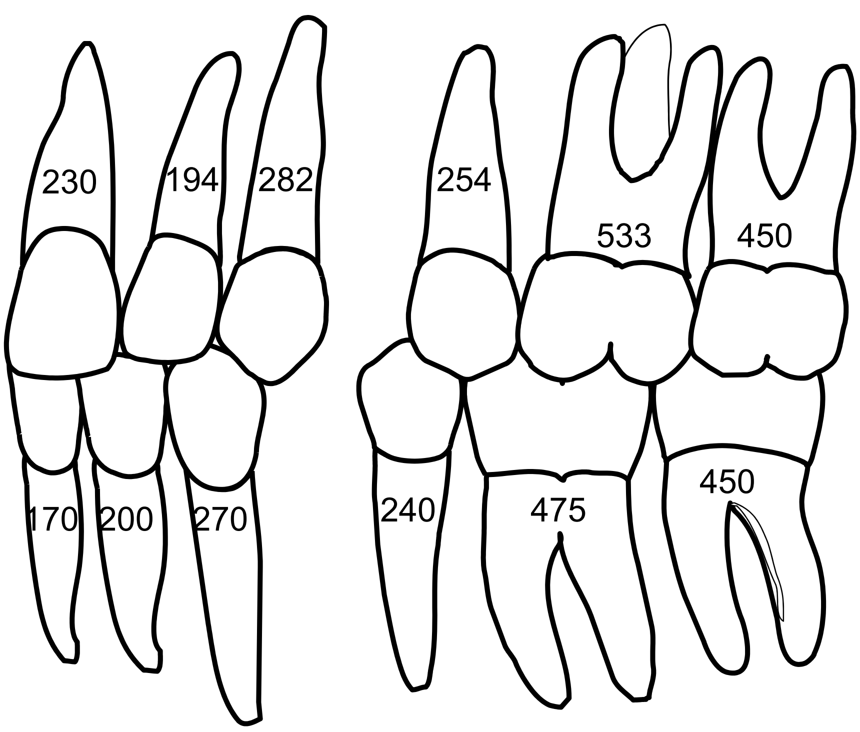


Fig. 23. Periodontal surfaces of each tooth. Source: Proffit W. Contemporary Orthodontics

extraction space closure is independent on periodontal surface of the anchor unit. The only mattering factors are: a) the resilience of the archwire the teeth move along and b) inter-bracket distance from canine to 1st molar. According to this theory, tip-back closest to the mesial margin of a molar-tube rotates anchor tooth-crown distally, whereas magnitude of either force as well as moment acting on canine depend on its distance ("d") from the tip-back bend . If the "d" distance is larger than 2/3 of the inter-bracket distance (fig. 24a), both teeth are subjected to rotating moments of different magnitudes, however of the same direction; thus net rotating moment responsible for anchorage not only has the maximal value, but acts in the direction of canine desired displacement. If the "d" distance equals 2/3 of inter-bracket distance (fig. 24b), although moment rotating favorably exists, however it is not increased with the moment rotating canine distally. Further decrease of the "d" distance" generates rotating moments of the same magnitudes, but of the opposite directions (fig. 24c), uprighting canine root and maintaining molar sagittal position. If such biomechanical standard is embraced, excluding 2nd premolar from the appliance increases the wire resilience and generates higher rotating moments of favorable directions (fig 25a) than including 2nd premolar into the anchor unit (fig. 25b). In other terms, on the contrary to the generally accepted concept, Mulligan's theory proves that decreasing periodontal surface of anchor unit may serve as better anchorage reinforcement.

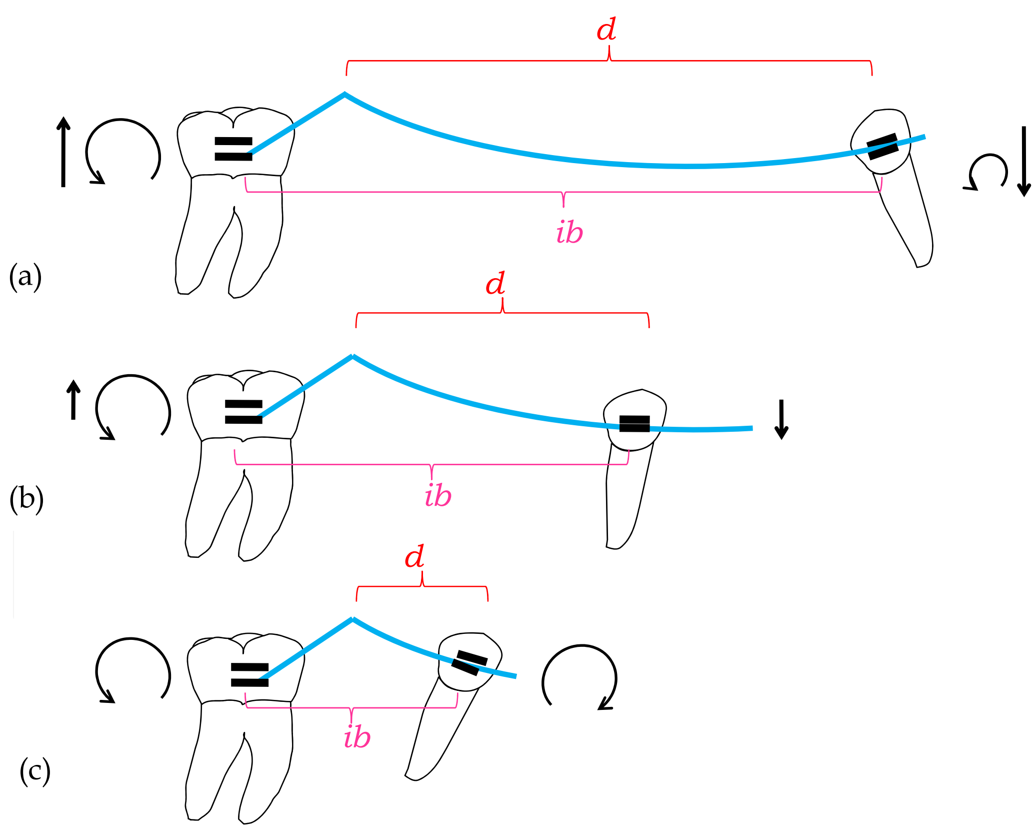
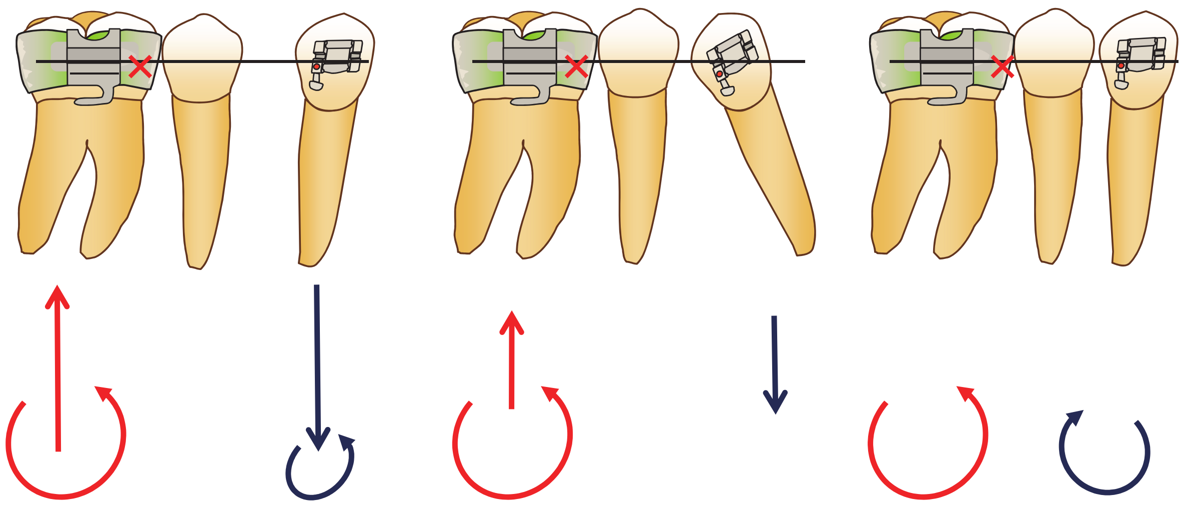
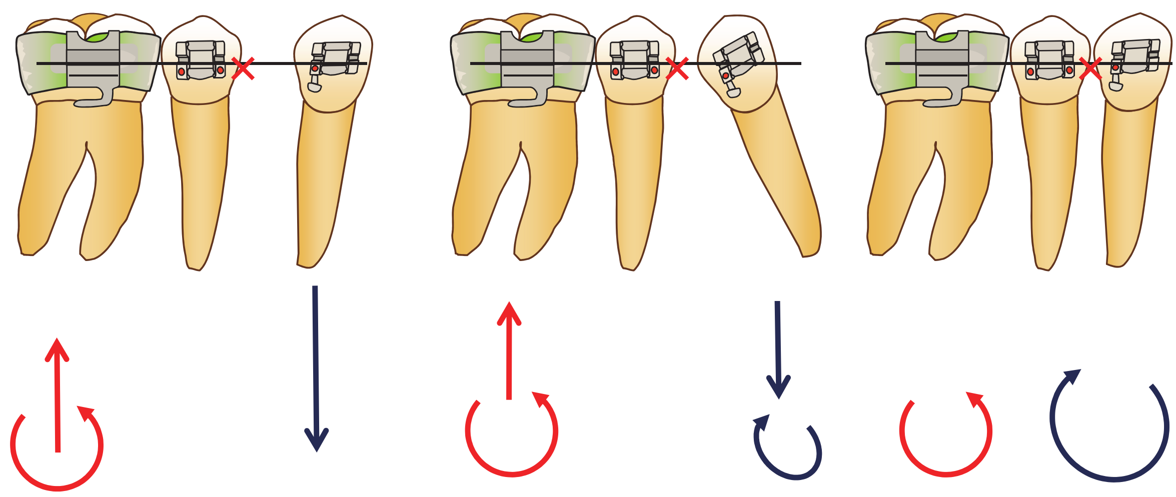


Fig. 24. Forces and moments acting on canine being displaced towards 1st molar, dependent on the distance „d" and inter-bracket distance „ib": a) d>2/3 ib, b) d=2/3 ib, c) d<2/3 ib; note that together with canine distalization (decreasing „d" distance) force value diminishes and moment direction changes after passing a „0" point. Direction of moment acting on canine results from archwire resilience and the distance from 1st molar



(a)



(b)

Fig. 25. Mulligan's concept: biomechanics of canine distalization if 2nd premolar is: a) excluded from the appliance, b) included in the appliance; "X"-gable bend, moments and forces acting on molars are marked in red, moments and forces acting on canines are marked in blue

2. Current look

Reasons of all the elaborated deliberations are scientifically supported: numerous research upon efficiency and efficacy of conventional anchorage [70-82], directly or indirectly confirm the poorness of their reliability. Despite high prevalence of the appliances reinforcing anchorage - especially in class II treatment - all hitherto discussed devices have certain disadvantages or could not provide anchorage for vertical tooth-movement[83-84]. Furthermore, in the face of overloading periodontal structures possibly leading to root resorption, tissue necrosis or cortical plate atrophy, extra-dental and intraoral source of anchorage has technically become natural point of clinical interest and evaluation: biocompatible implants.

Experimental study began already in 1945, when Gainsforth and Higley[85] introduced vitallium screws to distalize upper teeth (fig. 26). Since they failed (all screws were lost within approximately 1 month), boom for other animal experiments related to implants as anchorage reinforcement falls around turn of 1970 into 1980, after Brånemark and co-workers' success: osseointegration of prosthetic implant and bone. Factors such as alloys used for implant-manufacturing [86,87] as well as resistance to orthodontic loading with forces originating from fixed mechanics[88,89] differentiated the research material. Since the implants succeeded, they were proclaimed as "having the potential to be used as a source of firm osseous anchorage for orthodontics and dentofacial orthopedics"[90].

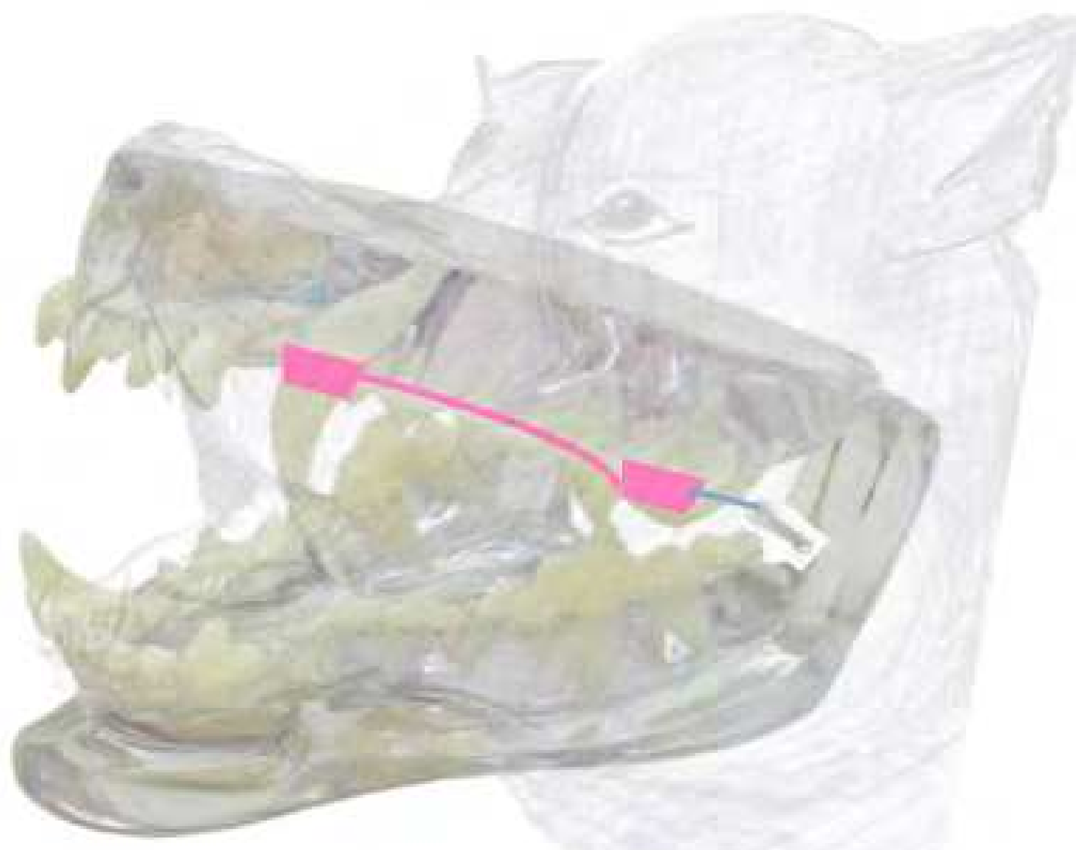


Fig. 26. Study design: Gainsforth and Higley, 1945

Shapiro and Kokich[91] were ones of the pioneers of pre-prosthetic implantation for orthodontic purposes in humans, slowly encouraging other clinicians[92-95]. However, obvious disadvantages of prosthetic implants, such as defeating interadicular placement, complicated surgical procedure associated with insertion, long-lasting osseointegration, biomechanical limitations and high cost were still of a major concern. Such circumstances attracted clinicians' great interest towards "slenderizing" commonly applied screws[96,97] and simplifying their insertion procedures[98] without compromising anchoring properties, thus leading to the development of 21st century orthodontic anchorage: miniscrew implants or TSAD (Temporary Skeletal Anchorage Devices). Their decreased sizes enabled placement in iteradicular spaces of either jaws, for many clinical purposes. Vertical displacements eg. alignment of canted occlusal plane (fig. 27a-c) intrusion of lower incisors (fig. 28a, b) or

(a) (b) (c)

Fig. 27. Alignment of canted occlusal plane using TSAD: a) initial occlusion, b) TSAD loading mode, c) final occlusion

(a) (b)

Fig. 28. Intrusion of lower incisors using TSAD: a) prior to TSAD loading, b) final result

lateral teeth (fig. 29a, b), as well as sagittal ones: protraction of lower molars with either sliding (fig. 30a) or segmented mechanics (fig. 30b) have eventually become facilitated and free of side effects. Clinical efficiency encouraged orthodontist to load TSAD multipurposely eg. applying distalizing and intrusive force on continuous (fig. 31a) or segmented (fig. 31b) archwire, extrusive and intrusive forces simultaneously (fig. 32) or even forces acting in three planes of space at the very same moment (fig. 33).

(a) (b)

Fig. 29. Intrusion of upper lateral teeth using TSAD: a) prior to TSAD loading, b) final result

(a) (b)

Fig. 30. Protraction of lower molars using: a) TSAD and sliding mechanics, b) TSAD and segmented archwires

(a) (b)

Fig. 31. Distalizing (D) and intrusive (I) forces on: a) continuous and b) segmented archwires

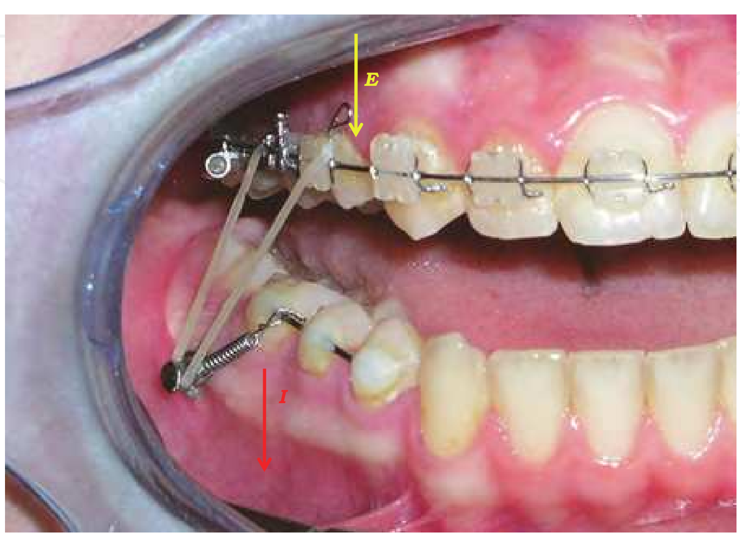


Fig. 32. Extrusive (E) and intrusive (I) forces acting spontaneously

Fig. 33. Transversal, vertical and sagittal forces acting simultaneously

Various practical demands entailed manufacturing and permanent improvement of different miniscrew implant-systems[90,99,100], all the more so that nobody informed about absolute stability (100% success rate) of TSAD. Our routine introducing of the miniscrew implants for anchorage reinforcement in treatment of many types of malocclusion[101-106] allowed us selection of the most versatile and convenient systems: Absoanchor® (Dentos, Daegu, South Corea) and Ortho Easy (Forestadent, Phorzheim, Germany).

Absoanchor® is available as the branch of different diameters, lengths and designs: from 1.2 to 1.6 mm in cross-section, 5 to 12 mm long, cylindrical or tapered, with flat or bracket-like heads, with long, short or no neck. However, in order to make such complex offer less confusing, especially for the beginners we recommend tapered miniscrew implants with small head and convenient hole in the conically-shaped neck; considering lengths and diameters: 6 mm and 1.6 mm in mandible and 8 mm 1.3 mm in maxilla should be chosen for vestibular insertion (fig. 34).

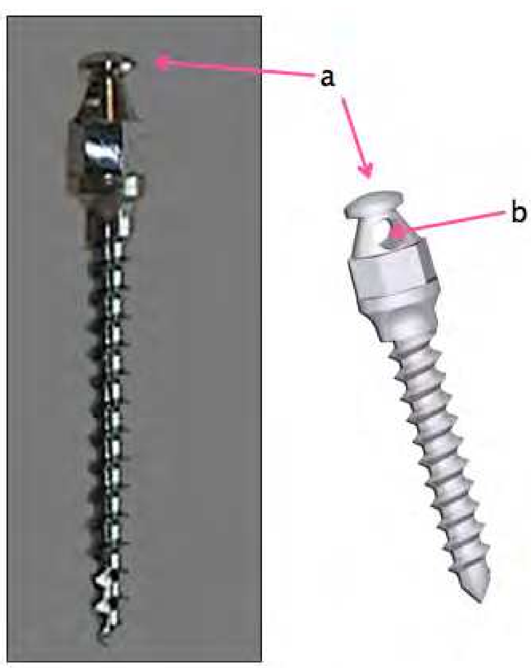


Fig. 34. Absoanchor®: a) small head, b) a hole for utility elements (ligatures, elastomerics)

Ortho Easy pins® are easier to handle: there is only one design available (fig. 35), therefore colour-coded different lengths (pink: 6 mm, violet: 8 mm) simplify the choice dependent on treatment indications and locations in the jaws: short miniscrew implant in mandible, long one in maxilla.

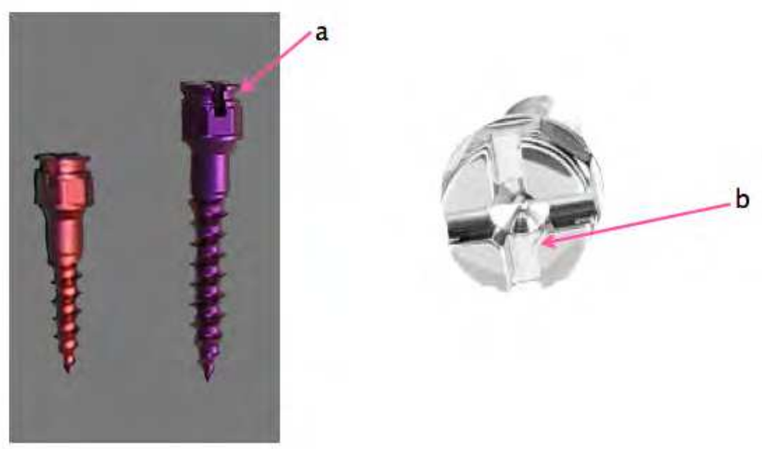


Fig. 35. Ortho Easy pins® : a) undercut facilitating ligating, b) rounded design of slot edges facilitating wire adjustment

Both systems are designed to insert into interadicular space, therefore they may be connected via coil spring with the elements of fixed appliances either bonded to the teeth or attached to the working archwire. It enables loading with forces of mesio-distal direction, so essential in correction of sagittal discrepancies with the vertical component: the most common malocclusions. Direction of the coil spring, dictated by mutual relation of TSAD position and height of attachment (hook) defines the line of force vector (fig. 36a, b).

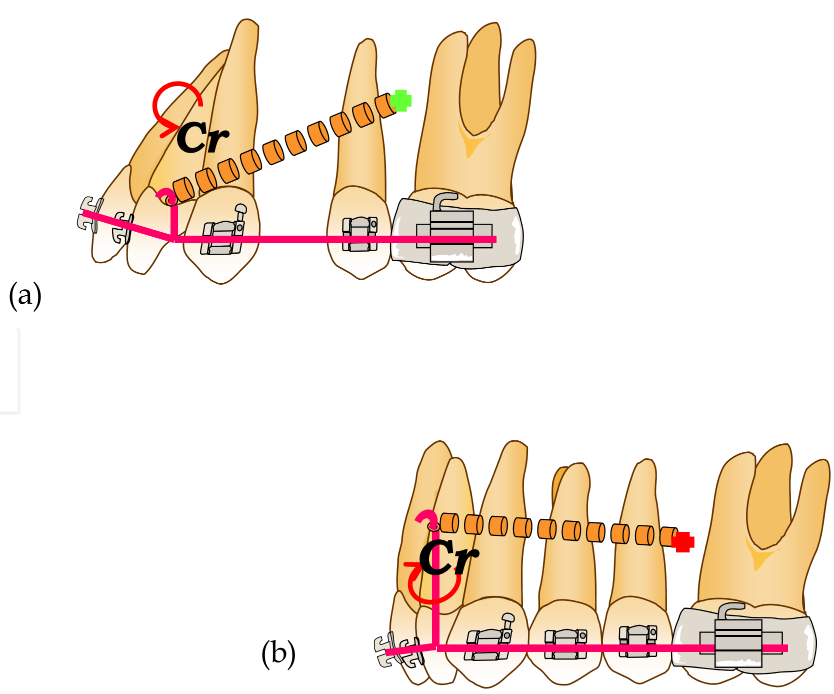


Fig. 36. Force vectors dependent on mutual relation of TSAD vertical position and height of attachment (hook) on the working archwire: a) rotating moment retruding incisors, b) rotating moment protruding incisors

Forasmuch it is obvious that TSAD position determines biomechanics of orthodontic treatment plan, nobody but orthodontists themselves should insert miniscrew implants. Although there is a myth that bending wires is far beyond the scope of the dentistry, we must not forget we are doctors and if the treatment fails we will be responsible for failures (fig. 37)! The best control is provided by the controller fully aware of the process, thus we would like to encourage our colleagues to become familiar with the details of insertion protocol providing the highest TSAD stability: Wroclaw protocol efficient in 93.43% and obtained after research upon both described TSAD systmes[105-108]. Selection of location for TSAD insertion bases on objective criteria: CT-images at the level of 5 – 7 mm apical of the alveolar crest analyzed by Park et al.[109], visualized the areas of the larger interadicular distances (ID) as well as the ones from the root to the cortical plate (R-CP). According to the provided data, TSAD should be inserted:

1. In maxilla: vestibularly, between central incisors (fig. 38a) or between 2nd bicuspid and 1st molar (fig. 38b) - mean ID = 3.18 mm,
2. In mandible: vestibularly, between 1st and 2nd bicuspids (fig. 39a) - mean ID > 2.20 mm) and between 1st and 2nd molars (fig. 39b) - mean ID = 4.57 mm, mean R-CP = 2.16-5.33 mm; although mean R-CP in mandible progressively increases distally from 1st molar, it is difficult to manipulate in this area, therefore mesial placement seems to be more convenient and still safe.

Fig. 37. Improper force vector causing undesired bite opening during planned space closure

(a) (b)

Fig. 38. Localization of TSAD in vestibulum of maxilla: a) between central incisors, b) between 2nd premolar and 1st molar; note height of the hook together with vertical position of TSAD form the line of force vector passing above the center of incisor resistance, thus forcing them labially during retraction. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

(a) (b)

Fig. 39. Localization of TSAD in vestibulum of mandible: a) between 1st and 2nd bicuspids, b) between 1st and 2nd molars. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

According to this study, palatal ID between 1st and 2nd molars warrants TSAD stability, however Ludwig et al.[99] in contrast report that anterior part of the palatal bone as the best zone for TSAD insertion (fig. 40). Nevertheless, eg. in case of 2 impacted canines, distal part of palate may serve as suitable area securing TSAD stability (fig. 41).
Once the location has been selected, local anesthesia is administered and

(a) (b)

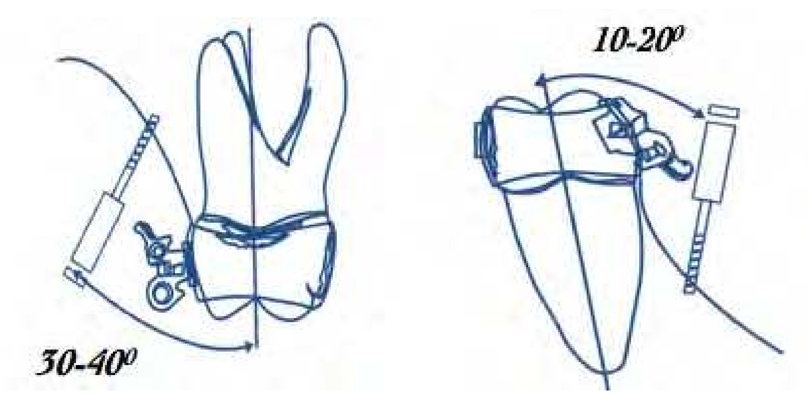
Fig. 40. Localization of TSAD on palate recommended by Dr. B. Ludwig; picture by the courtesy of Dr. B. Ludwig

Fig. 41. Localization of TSAD on palate recommended by Prof. Hyo-Sang Park

(a) (b)

Fig. 42. Establishing of interadicular position of TSAD: a) initial position of explorer, b) final position of explorer. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

precise determination of TSAD position takes place. It is accomplished with the dental probe initially oriented parallel to the occlusal plane, with the bend tightly pressed between the crowns of the adjacent teeth with (fig. 42a), then rotated 90^0 towards gingiva (fig. 42b): its tip is located directly in the middle of the interadicular distance. Pressing the tip of explorer firmly against gingiva and oral mucosa causes slight indentation and local ischemia of soft tissues serving as the reference for mesio-distal position of the implant. Vertical position is established along the ischemic line. After vertical, short (4 mm) stab incision, wound margins are pushed aside: this incision is mandatory in order to avoid risk of implementation connective tissue into the screw course during TSAD insertion. Subsequently, a pit is made in cortical plate using a round bur oriented perpendicularly to the bone surface , thus followed with a pilot drill angulated at 30-40^0 and 10-20^0 to the root axes in maxilla and mandible respectively (fig. 43a, b). This is a pre-drilling method, less forceful for the alveolar process due to significantly lower insertion torque[110], however more time consuming than self-drilling one.



(a) (b)

Fig. 43. Angulation of Absoanchor®: a) in maxilla, b) in mandible. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

Ambidexterity of an operator, utilized in Wroclaw protocol, secures the most accurate view into the insertion area, with no distortion. Drilling with the speed not exceeding 500 rpm requires massive irrigation to avoid overheating of the bone. The miniscrew implant may be

inserted with a manual or engine screw driver, however manual implantation is recommended (especially for the beginners), since during manual insertion orthodontists may notice even minor increase in resistance often related to root contact. If this occurs, it is mandatory to unscrew implant totally and to apply it in a different angulation.
Post-operative inflammation requires no antibiotics[108], however 2-week postponement of loading allows total cease of symptoms.
Periapical radiograms in three projections - perpendicular and two oblique ones to assess root contact recommended by Park[111] are excluded from Wroclaw protocol: one must not neglect neither distortion nor dose protection. In our method, stable position of miniscrew two weeks after insertion indicates no root contact, which allows loading TSAD with initial force value of 50 g, still within primary stability period (fig. 44). This value may be increased accordingly to the treatment needs, after 3 months, up to 180 g per side thus matching data provided by many researchers:

1. forced eruption of impacted tooth: 50g for canine[112] and 80 g for molars[113],
2. intrusion of posterior teeth: 50 g buccolingually per tooth[114], 90 g[115], 100 g[116] or 150-200 g[117],
3. group sagittal movement: 150 g for retraction of 6 front teeth[118] or 180 g[101] for distalization of all upper teeth.

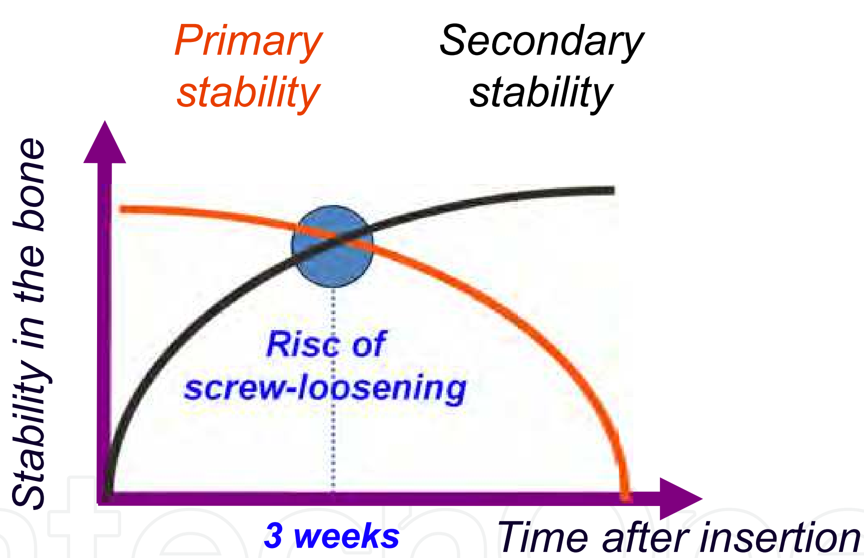
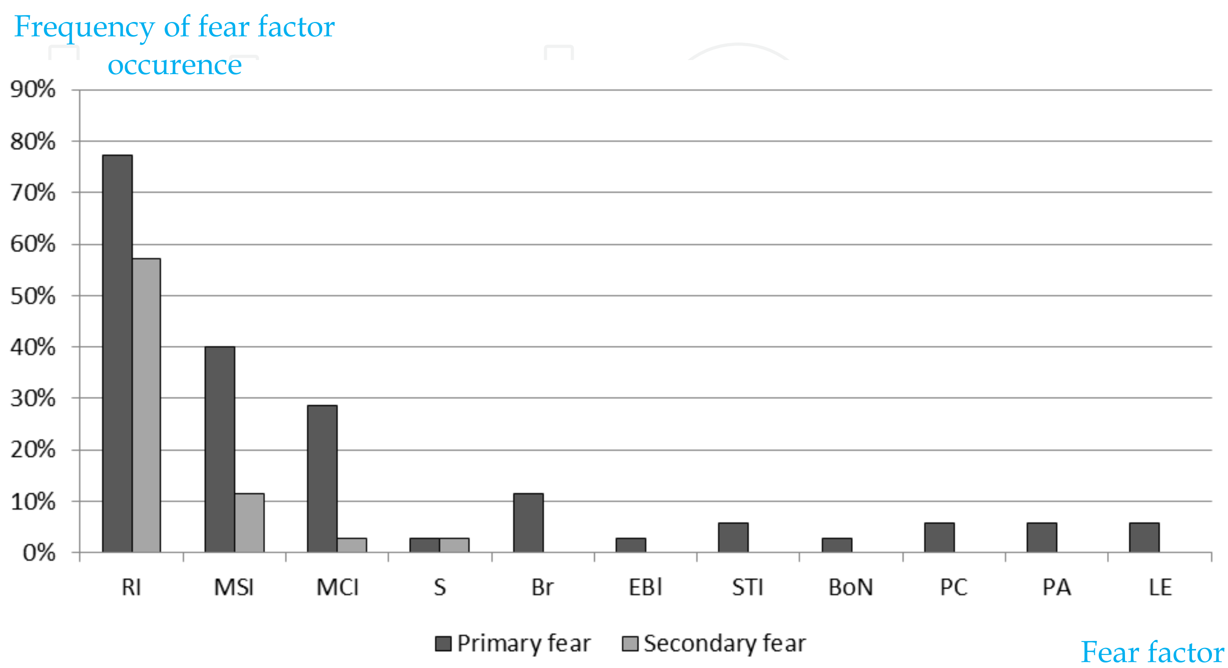


Fig. 44. Diagram illustrating periods of TSAD stability

In serviceable survey of orthodontists[119] evaluation of fear rate before and after TSAD insertion displayed different results. Mean fear level ranked before experiment reached 4.6 and significantly ($p<0.05$) diminished to 3.2 after four trials of TSAD insertion. Factors responsible for fear rate before and after TSAD insertion differed quantitatively and qualitatively (fig. 45). Fear rate before TSAD insertion was mostly associated with risk of injury: dental root (77.14% of clinicians), maxillary sinus (40.00%) or mandibular canal (28.57%). Only few orthodontists submitted other factors such as uncontrolled bur sliding while drilling, breakage of either drill or TSAD, excessive bleeding, soft tissue impaction into the drilled hole, bone necrosis, postoperative complications, and patient's unwilling attitude towards TSAD insertion as well as personal lack of experience. After TSAD insertion, fear rate associated with risk of injury evidently decreased: fear of dental root, maxillary sinus and mandibular canal injuries were submitted by 57.14%, 11.43% and 2.85% of clinicians respectively. Furthermore, spectrum of possibly frightening factors restricted after four trials; besides risk of injury, only uncontrolled bur sliding while drilling remained the fear factor for 2.85% of the surveyed group.



RI - root injury, MSI - maxillary sinus injury, MCI - maxillary canal injury, S - uncontrolled bur sliding while drilling, Br - breakage of either drill or MSI, EBl - excessive bleeding,
STI - soft tissue impaction into the drilled hole, BoN - bone necrosis, PC - postoperative complications, PA - patient's unwilling attitude towards MSI insertion, LE - lack of experience

Fig. 45. Evaluation of fear rate before and after TSAD insertion. Source: Antoszewska J, Trześniewska P, Kawala B, Ludwig B, Park HS. Qualitative and quantitative evaluation of root injury risk potentially burdening insertion of microscrew implants. Korean J.Orthod. 2011;41,2:112-120

Although TSAD are valuable tools for gaining excellent anchorage, especially in non-compliance patients, their stability is still a problem requiring further investigation. The research of Liou et al.[120] has proven that stable TSAD have not kept their initial position during treatment and tipped even 1.5 mm still serving as an excellent anchorage. Nevertheless establishing risk factors of excessive implant mobility impeding orthodontic force application is crucial for treatment success. So far, the list assessing the highest number of parameters related to TSAD failures, based on the Kaplan–Meier product-limit estimate specifies[105]: low position of the line connecting oral commissures (fig. 46), decreased overbite (fig. 47), Angle class III (fig. 48), vertical location in attached gingiva in mandible (fig. 49), right side of mandible between 1st and 2nd molars (fig. 50), lower molars intrusion and class II traction (fig. 51). Clinical parameters favoring failures are also listed: male sex, age < 20, upper midline shift to the right, centered lower midline and, class III on canines - all of them evident already at the clinical examination, therefore easy to manage and control.

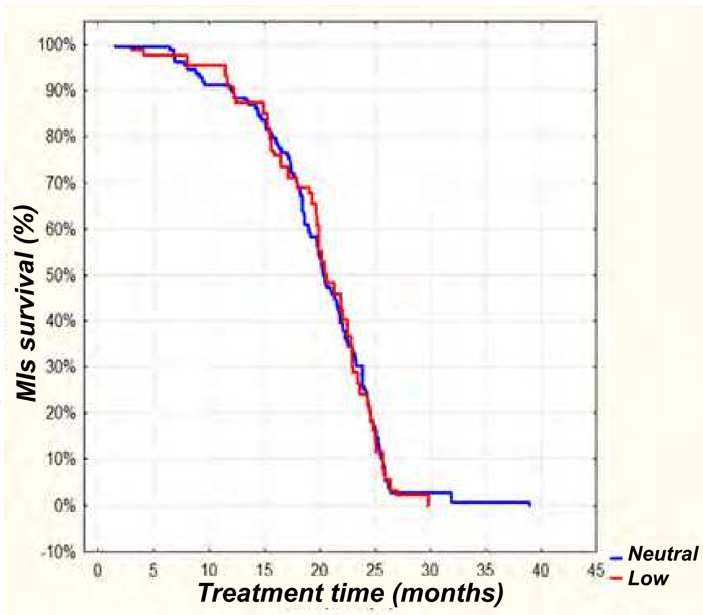


Fig. 46. TSAD stability in relation to position of the line connecting oral commissures: neutral (passing stomion) and low one (beneath stomion). Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

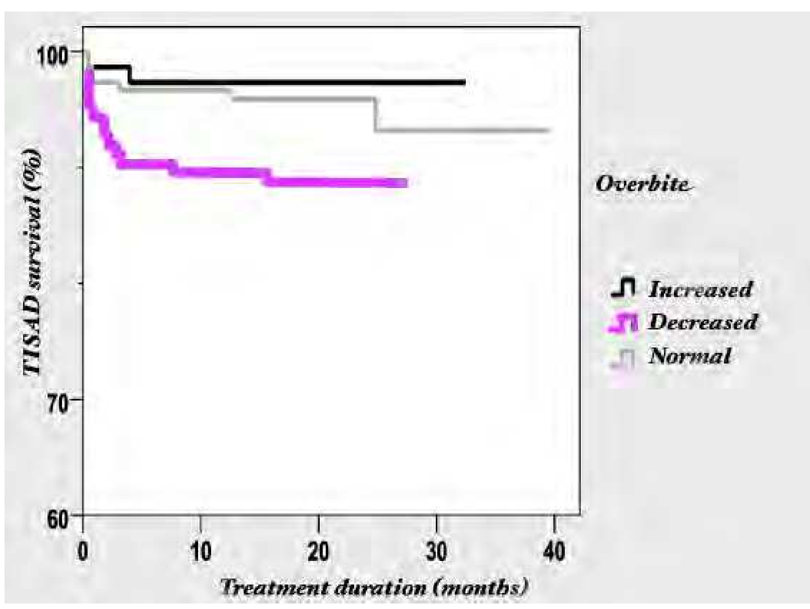


Fig. 47. TSAD stability in relation to an overbite: DB – deep bite, OB – open bite, NOB – normal overbite. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7. Source: Antoszewska J, Papadopoulos M, Park HS, Ludwig B. Five-year-experience with orthodontic miniscrew implants: a retrospective investigation of the factors influencing the success rates. Am J Orthod Dentofacial Orthop 2009;136;2:158.e1-158.e10 (on-line), 158-159

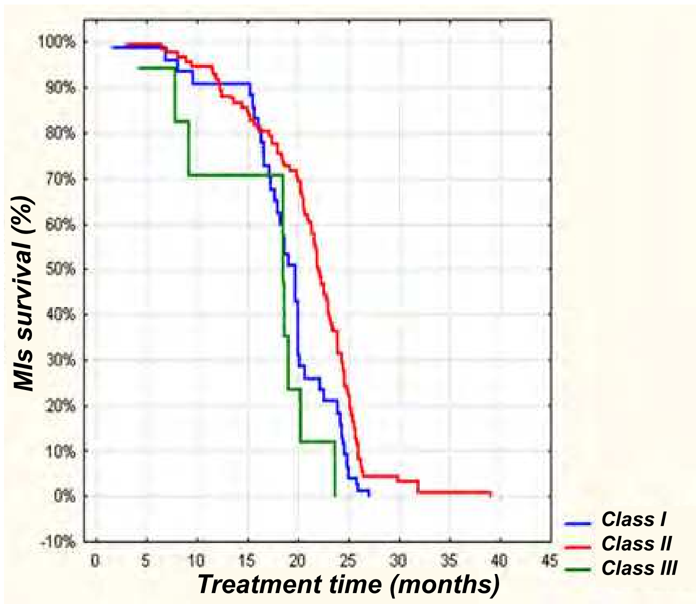


Fig. 48. TSAD stability in relation to the Angle class. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

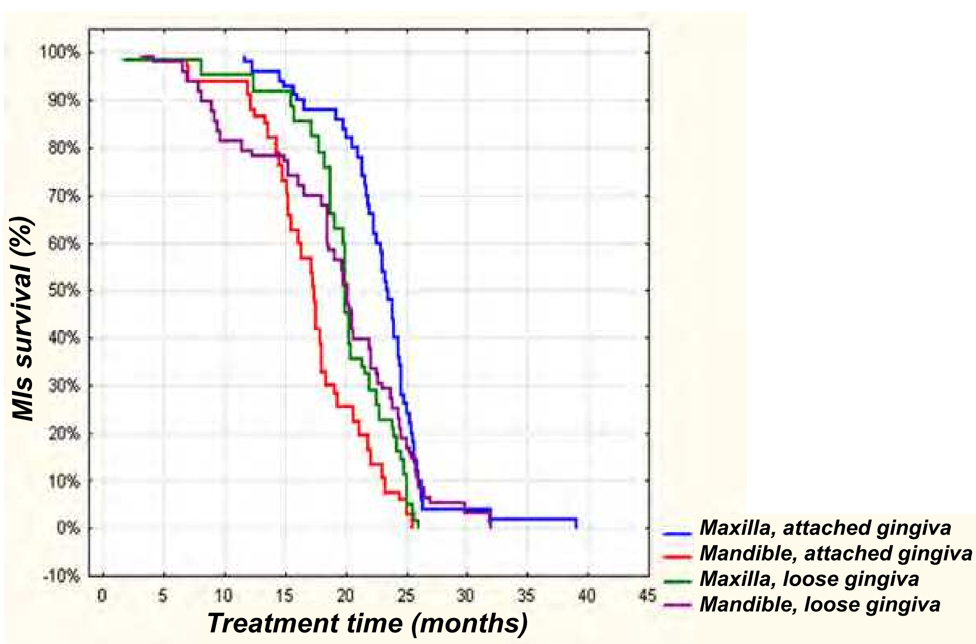


Fig. 49. TSAD stability in relation to its vertical position. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

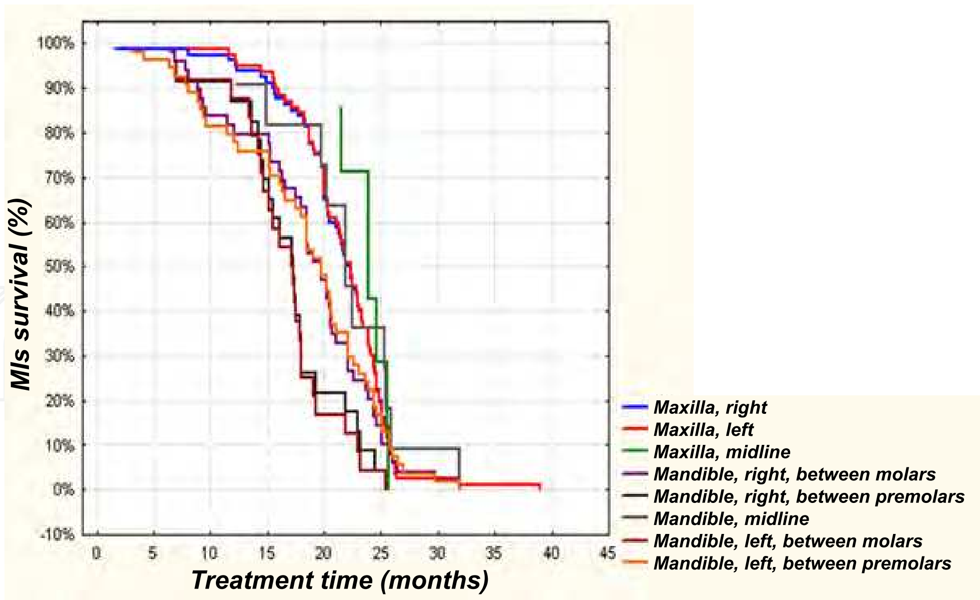


Fig. 50. TSAD stability in relation to its position along the dental arch perimeter. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

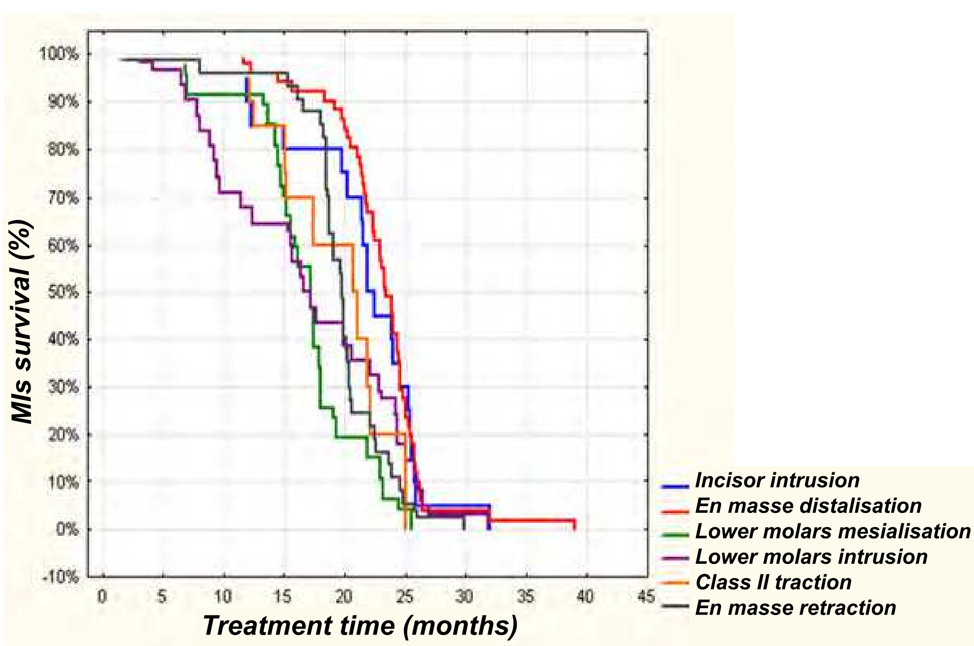


Fig. 51. TSAD stability in relation to orthodontic displacement. Source: Joanna Antoszewska (2009) Wykorzystanie tymczasowego zakotwienia kortykalnego w leczeniu zaburzeń zgryzowo-zębowych. Wrocław : Akad. Med., 5; 111 s. (Rozprawy Habilitacyjne Akademii Medycznej we Wrocławiu). ISBN 978-83-7055-489-7

Considering rate of stability, certainly mini plates prevail over single miniscrew implants, however the former ones demand on more complex surgical protocol[121-126]. Nevertheless, rapid development of orthodontic anchorage design as well as progressively increasing interest of practitioners towards application of mini plates in mostly simple manner already provoked the positive feedback: system addressed to orthodontists only[127-134].
Summing up, miniscrew implants and mini plates increasing popularity among clinicians is quite likely to displace conventional appliances for anchorage reinforcement, therefore "gravity center" of knowledge provided in this chapter has been moved towards details of planning and application of temporary skeletal anchorage devices.

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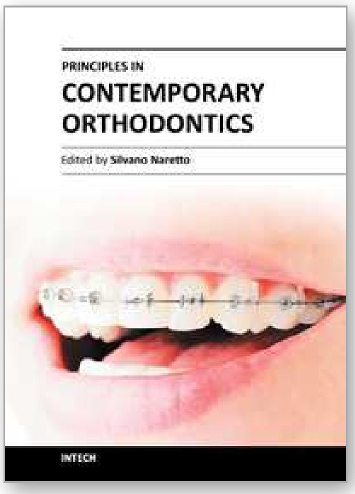

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Orthodontics is a fast developing science as well as the field of medicine in general. The attempt of this book is to propose new possibilities and new ways of thinking about Orthodontics beside the ones presented in established and outstanding publications available elsewhere. Some of the presented chapters transmit basic information, other clinical experiences and further offer even a window to the future. In the hands of the reader this book could provide an useful tool for the exploration of the application of information, knowledge and belief to some orthodontic topics and questions.

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