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CHALLENGES, STANDARDS AND PROSPECTS IN THE THERAPY OF ORTHODONTIC TRACTION OF IMPACTED MAXILLARY CANINE – SURGICAL PHASE

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Introduction

Maxillary canine is the third tooth from the midline, positioned between frontal and lateral zone. It is usually characterized by the longest root of all teeth and the longest eruption period. It is exposed to tremendous masticatory pressure and located in the smile zone. The tooth erupts between 11-12 years of age, while the root completion occurs at the age 13-15 \(^1,2\). Impacted tooth (impactio dentis) is a tooth whose eruption is considerably delayed, and for which there is clinical or radiographic evidence that further eruption may not take place due to the existence of various barriers. In dentistry, the terms impactio and retentio are explained as failure of tooth eruption caused by detectable and undetectable reasons for tooth emergence, respectively.

The etiology of canine impaction is multifactorial, encompassing both genetic and local factors \(^3,4\). The delay or complete cessation of tooth eruption may be due to a long and tortuous eruption pathway, trauma, improper position of the tooth germ, fibrous callus in mucoperiosteum, sclerotic changes in bone, mucosal thickening, existing impacted teeth, hyperdontia, odontoma, cysts, tumors, etc.

Upper canines are very frequently reported impacted teeth, second only to third molars. The prevalence of impacted maxillary canines ranges between 0.92 % and 2.56 % \(^5-7\). Upper canine impaction is reported in 3% of population, with a gender prevalence rates being 70% and 30% in females and males, respectively. The incidence of palatal location of impacted maxillary canines is three times more frequent than that of labial location. 85% of palatally impacted canines have sufficient space to erupt into the dental arch contrary to only 17% of labially impacted ones.

Unerupted maxillary canine can be extracted or preserved. Extraction of the deciduous canine as an interceptive treatment in children with canines positioned palatal \(^8\). Therapy options include interceptive extraction of primary canine and placement of space maintainer; surgical extraction of the canine and moving the first premolar into its site; surgical extraction of the canine and use of fixed denture (bridge or implant); exposure of the canine to enable spontaneous eruption and growth; exposure of the canine and active
traction to move the tooth into the dental arch; exposure of the canine and active traction to move the tooth into the dental arch using orthodontic implant as an anchorage; transplantation of the canine with follicle; no active treatment (monitoring) 5. For several purposes, preservation and adequate positioning of the canine into the dental arch is desirable. Treatment decision is made exclusively by an orthodontist. Preservation of the tooth implicates the removal of physical barriers in its eruption path and enabling its spontaneous positioning to desired site (provided that there is evidence of potential growth, incomplete growth and sufficient space). Exposure of impacted tooth is managed using open and closed surgical techniques. The term “tooth denudation” is used for the open method. After surgical procedure, the tooth is uncovered from tissues, becoming visible in the oral cavity. The term “tooth liberation” is associated with closed surgical technique. The tooth remains invisible after surgery. The method was first described by Hunt 9 and McBride 10. In case when the cycle of tooth root growth and development has not yet been completed, the tooth might be allowed to erupt spontaneously. If the growth cycle has been completed or the tooth is improperly positioned, orthodontic traction management is required. In closed method, the elements of traction appliances are placed intraoperatively. Moisture and blood contamination of conditioned enamel results in weakening the adhesive bond with the tooth. Activation of the traction (after surgery) can lead to adhesive bond failure, thus, an additional surgical procedure might be required. A range of traction methods and appliances for management of impacted tooth is available. The system should be safe, immobile, permanent and stable. The adhesion bond itself is highly complex.

**Radiographic examination – timely diagnosis of impacted canine**

Radiographic examination is indicated in case when the tooth has not erupted after the expected optimal eruption time, while the same tooth erupted normally on the other side. The absence of tooth (anodontia) and exact position of impacted tooth should be determined. Scan analysis identifies the position of impacted tooth, root morphology (curvature of the apex), relationship to adjacent teeth, distance from the alveolar bone limbus, relationship towards maxillary sinus and nasal cavity, possible adjacent tooth root resorption (mostly second incisor) 11, presence of follicular cyst, odontoma and supernumerary teeth. Periapical radiography offers only basic information 12. Position of teeth was determined based on two images, phenomenon of parallax, Clark’s rule.
Commonly, the term BAMA rule (buccal always moves away) is used. Sometimes, an occlusal radiographs image was used as a supplement.

Orthopantomogram (OPG) is standard radiography, which is widely applied in routine practice. Lateral cephalometry and the postero-anterior cephalometry provide data that are critical for adequate therapy planning. Novel digital technologies and software analysis increased the processing speed and accuracy for a range of parameters, which undoubtedly led to improvement of therapeutic approach. Ericson and Kurol defined the term “sector analysis”\(^\text{13}\) that involves three sectors in an OPG scan that enable differentiation between diverse impaction types. Four lines in the OPG scan determine three sectors defining impaction types. These include medial line (interincisal) and lines extending along the axes of first premolar and first and second incisor. The position of the canine crown tip within specific sector is determined. Moreover, the $\Theta$-angle formed by the longitudinal axis of canine tooth with interincisal line is defined. This analysis is vital for the prognosis of the success of orthodontic traction procedure. The risk of root resorption of lateral incisor is increased for some 50% if the canine is positioned in sectors 1 and 2 and with a $\Theta$-angle above 25°.

Cone beam computed tomography (CBCT) enables an accurate and precise indication for tooth traction or extraction. The method prevents diagnostic errors that were common in the past and should evolve into the new standard of imaging\(^\text{14-18}\).

**Major reasons for therapy failure and surgical techniques**

Therapy failure mainly considers the dropping out of active traction therapy. In an ideal situation, extraction should be indicated before starting the orthodontic therapy. The tooth is surgically extracted to prevent wasting of time for creating sufficient space to accommodate teeth in the jaws.

According to the relevant protocol, a presence of an orthodontist is required during surgical procedure in order to get an insight into the position of tooth and surrounding tissue structures and estimate appropriate position of traction appliances\(^\text{19,20}\). Extremely rarely, the orthodontist might change his decision about therapeutic approach during the first surgical tooth exposure. In that case, upon removal of tissue structures covering the
crown, orthodontist may decide that tooth extraction is highly indicated and informs oral surgeon and parents thereof.

The failure of adhesive bonds can occur during the period of tooth traction and consequent repeated surgical procedure. Quite often, the patients lack motivation to continue with the treatment due to possible failure. The selection of relevant surgical procedure highly determines further treatment course. Open surgery has certain advantages such as: the presence of orthodontist is not required; detachment of the bracket does not indicate repeated surgery. The advantages of closed surgery include fast wound healing, less discomfort for the patient, good postoperative hemostasis, lesser functional disorder and bone removal, immediate application of orthodontic traction, more consistent tooth-to-adhesive bond and feasibility of the procedure even in close proximity of adjacent tooth root resorption. In case of closed surgery, the presence of orthodontist is highly required.

**Intraoperative reasons for therapy failure**

Poor (or broken) bond of the orthodontic appliance at the impacted tooth can compromise the success of orthodontic surgical treatment.

The advancements in the field of adhesives and composite materials enabled the placement of orthodontic brackets onto the impacted tooth. In case of closed technique of tooth exposure, the adhesion bond between unerupted tooth and traction anchorage must be strong because of the resistive force of surrounding soft tissues. Such force acts in an opposite direction to that of tooth traction and has a tendency to break the bond between the tooth and orthodontic appliance. In case of bond failure, repeated surgical procedure will be inevitably indicated. This is the major problem to be avoided and the issue of reinforcement of the bond is to be emphasized. The basic bond is that between the enamel and adhesive material, Miletić. Furthermore, important bonds include adhesive-to-composite, composite-to-bracket, bracket-to-connector and connector-to-orthodontic appliance attachments.

A comprehensive, team-based approach to bracket positioning is imperative. The placement of traction elements is performed by the orthodontist. Hemostasis performed by surgeon is prerequisite for the successful outcome of this stage. Sometimes, persistent
hemorrhage requires application of pressure on bleeding spot using blunt instrument, bone wax or cauterization. How to overcome the problem of conditioned enamel contamination and failure of enamel-to-adhesive bond? Intraoperative placement of traction elements is complicated by humidity in mouth cavity (saliva, blood), Varga 26. After removal of the acid and enamel drying, the adhesive is applied onto the tooth and light-polymerized. Majority of orthodontic adhesives used for bracket sealing is hydrophobic, i.e., their bond strength decreases significantly in humid environment. Thus, the procedure should be performed quickly and blood penetration must be prevented. If contamination still occurs, blood should be removed with alcohol and cotton pellet and dried using sterile gauze.

The emergence of novel 7th generation monophase (self-etch) hydrophilic adhesives can substantially improve the tooth-to-adhesive bond strength in the presence of contamination, 27. One-step procedure for conditioning and application of the adhesive decreases the risk for moisture contamination of the tooth. These adhesives show lower adhesion strength as compared to hydrophobic ones, yet only under ideal conditions. However, in humid conditions, hydrophilic adhesives demonstrate higher adhesion strength than the hydrophobic ones.

It has been observed that the self-etching adhesives demonstrated higher bond strength to dentin than enamel. The fifth protocol, “selective etching”, has been introduced to improve the enamel-to-self-etching adhesive bond. The protocol entails enamel treatment with orthophosphoric acid during 15 seconds. The self-etching monocomponent adhesive removes potential moisture remaining from etched enamel. The adhesive is applied and allowed to penetrate for 20 seconds. This step is followed by polymerization for 20 seconds 25,28.

A wide variety of adhesive systems is available on the market. All of them consist of three components – acid, primer and bond. The systems can be divided into two groups: total-etch and self-etch adhesives. Total-etch adhesives encompass three-step acid-etch systems (acid, primer and bonding agent as three separate components) and two-step acid-etch systems (acid as a separate component and single bottle of primer+bonding agent). Self-etch systems can be either two-step self-etch adhesive (self-etching primer and bond) or monophase self-etching adhesive (all components in a single bottle).

The clinician should be focused on providing dry operating environment and fixing the brackets or chain with composite, whereas adhesive application itself is not considered
crucial factor for the stability and durability of the bond. The knowledge of orthodontists and oral surgeons about adhesive systems and protocols is still limited. Modern adhesive application protocols were developed and described by Van Meerbeek \textsuperscript{29} in 2003. Two-step acid-etch adhesive is most commonly used. One-step self-etch adhesives are not widely used in everyday routine.

The answer to the question whether to use monophase self-etching adhesive can be obtained only from an in vitro experiment \textsuperscript{30,31}. The use of extracted teeth enables simulation of specific conditions and measurement of shear bond strength. Majority of studies investigated the force applied in an angle of $90^\circ$ (pull-out strength) commonly in ideal and very rarely under humid conditions. Experimental settings mimicking authentic surgical environment (blood, moisture) and shear de-bonding are very rare \textsuperscript{32,33}. Clearly defined protocols with guidelines for selection of an adhesive to be used in conditions of contamination (moisture, blood) are still lacking. The authors of this paper carried out a study on these basics in order to introduce a safer protocol of work. The improvement of micro-mechanical bonding in conditions of enamel contamination and recommendations for the type of adhesive to use is the goal of future research. Oonsombat \textsuperscript{34} and Seondrini \textsuperscript{35} pointed out the drop of shear bond strength associated with blood contamination. The authors also emphasized that application of self-etch primers produces stronger bonds, which is due to hydrolysis that facilitates partial cleaning. The qualitative properties of $7^{th}$ generation monophase self-etch adhesive systems have not yet been adequately investigated in surgical environment, where blood and physiological saline can cause enamel contamination. Some of these agents do not contain hydroxyethyl methacrylate and bisphenol A (either its derivatives) and acetone provides evaporation of residual water. Such adhesive systems show high shear bond strength along with fluoride-releasing behavior, while conditioning, priming and bonding processes take part simultaneously \textsuperscript{36}.

After adhesive polymerization, the composite material is applied onto the orthodontic bracket, placed onto the adhesive zone on the tooth and light-polymerized. Bracket conditioning entails the placement of ligature wire onto the bracket head. This technique is most commonly practiced \textsuperscript{37}.

In closed surgery technique, where impacted tooth is covered with a flap and thus invisible, the only link with the outside environment is established via wire ligature, gold-chain or elastic bands attached to the bracket before bonding, \textsuperscript{5,19}. Such mediators are
termed connectors. Surprisingly, gold-chains have been widely accepted and approved thanks to their adequate strength and easy handling and placement, regardless of their high cost and poor availability on the market. Ligatures made of stainless steel are simpler alternative. Stainless steel wire is safe in hands of both orthodontists and oral surgeon.

Standard brackets are considerable in size and with a high, wide and sharp profile. The body of the bracket moves along with the tooth during its eruption and produces irritation of the mucosa. The tension of wire ligature twisted around the bracket towards the arch increases friction against the soft tissue, thus leading to inflammation and potential irreversible damage of periodontal tissues. Novel trends in orthodontics involve direct placement of 14k gold chains with small chain links that are gradually removed as the tooth erupts. In this way, maximum enamel surface is conditioned (wider than bracket surface), the chain is vertically bonded and covered with the composite. Contrary to the brackets, there is no coalescence of the composite and soft tissue; thus, the resistance of soft tissue is minimal. Consequently, every bracket placed on the tooth (when using closed technique) should be small enough and low-height profile in order to produce minimum adverse effect on surrounding soft tissues.

Conclusion

The prerequisites for successful treatment outcome of orthodontic traction of retained upper canines include patient’s motivation and compliance with a long-term therapy as well as systematic and comprehensive planning of treatment course. Team-based approach is indispensable. From technical point of view, maximal concentration of both orthodontist and oral surgeon is essential, especially after enamel conditioning. In case of blood contamination, the use of 7th generation adhesive is indicated. Application of gold chain attachment is recommended, along with maximal conditioning of enamel area. The chain should be covered with composite to minimize the resistive force of the tissue. Mini implants are increasingly used as an anchoring center when pulling impacted canines.
References

1. Proffit WR, Fields HW, Jr. Sarver DM. Ortodoncija. 4th ed. Zagreb: Slap; 2009.
2. Liversidge, H. M. Tooth eruption and timing. In J. D. Irish & G. R. Scott (Eds.), A companion to dental anthropology. John Wiley & Sons, 2015, Inc, pp. 159–171.
3. Simić S, et al. The prevalence of peg-shaped and missing lateral incisors with maxillary impacted canines. Vojnosanit Pregl 2019; 76(1): 61-66.
4. Becker A, Chaushu S. Etiology of maxillary canine impaction: a review. Am J Orthod Dentofacial Orthop 2015; 148:557-67
5. Becker A. The Orthodontic Treatment of Impacted Teeth. Wiley-Blackwell; 2012.
6. Mason C, Papadakou A, Roberts GJ. The radiographic localization of impacted maxillary canines: a comparison of methods. European Journal of Orthodontics 2001; 23(1) 25–34
7. Al Fawzan AA, Alruwaithi M, Alsadoon S. Prevalence of Maxillary Canine Impaction in Orthodontics At Eastern Riyadh Specialized Dental Center. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS). 2017; 16(1) 72-74
8. Naoumova J, Kurol J, Kjellberg H. Extraction of the deciduous canine as an interceptive treatment in children with palatally displaced canines - part II: possible predictors of success and cut-off points for a spontaneous eruption. European Journal of Orthodontics 2015; 37(2):219-29.
9. Hunt NP. Direct traction applied to unerupted teeth using the acid-etch technique. Br J Orthod 1977; 4:211-212.
10. Mc Bride L. Traction - a surgical/orthodontic procedure. Am J Orthod 1979; 76:287-299.
11. Chaushu S, et al. Predisposing factors for severe incisor root resorption associated with impacted maxillary canines. Am J Orthod Dentofacial Orthop 2015; 147:52-60.
12. Sheth S. A Comparison of Radiation Dose Absorbed During Localization of Bilateral Impacted Canines: Periapical Radiographic Techniques Versus Small-Volume Cone Beam Computed Tomography [dissertation]. New York: Stony Brook University, School of Dental Medicine , 2018; (USA)
13. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. European Journal of Orthodontics. 1988; 10:283-295.

14. Liuk IW, Olive RJ, Griffin M, Monsour P. Maxillary lateral incisor morphology and palatinally displaced canines: A case-controlled cone-beam volumetric topography study. Am J Dentofacial Orthop. 2013; 143:522-526.

15. Mihailović B, et al. Computer-aided technologies in diagnostics and therapy of impacted teeth. Vojnosanit Pregl 2011; 68(4): 353-358.

16. Majstorović N, et al. Dental arch monitoring by splines fitting error during orthodontic treatment using 3D digital models. Vojnosanit Pregl 2019; 76(3):233-240.

17. Ramegowda S, Khillon N. Evaluation and assessment of maxillary lateral incisor in cases of palatally impacted canines - A CBCT Study. Indian Journal of Orthodontics and Dentofacial Research, April–June 2016; 2(2):39-42.

18. Yerragudi N, et al. Use of cone beam computed tomography in the preoperative evaluation of impacted teeth: a prospective study. International Journal of Scientific Research. 2019; 8(6):31-36.

19. Kokich VG, Mathews DP, Ortodontska i hirurška terapaija impaktiranih zubi. Zagreb: Quinnessence Publishing Co; 2014.

20. Mirković S, Šarčev I, Bajkin B, Tadić A, Đurđević Mirković T. Orthodontic-surgical therapy of retained upper canine. Med pregl 2012; LXV (5-6):233-237.

21. Becker A, et al. Surgical exposure of impacted canines: Open or closed surgery? Seminars in Orthodontics. 2016; 22(1):27-33.

22. Becker A, Chaushu S. Surgical treatment of impacted canines: what the orthodontist would like the surgeon to know. Oral and Maxillofacial Surgery Clinics. 2015; 27(3):449-458.

23. Sylvia A, et al. Primary failure of eruption and other eruption disorders - Considerations for management by the orthodontist and oral surgeon. Seminars in Orthodontics. 2016; 22(1):34-44.

24. Becker A, et al. Failure of treatment of impacted canines associated with invasive cervical root resorption. Angle Orthod. 2013; 83:870-876.

25. Miletić V, Santini A. Dentalni adhezivni sistemi. Beograd: Univerzitet u Beogradu, Stomatološki fakultet; 2012.
26. Varga S, M. M. Suvremeni adhezivni sustavi. Acta Stomat Croat 2005; 465-470
27. Olsen MB. The effect of phosphoric acid etch in conjuction with self-etching primer on enamel surfaces and resultant orthodontic bracket bond strength. [dissertation]. University of Missouri-Kansas City, School of Dentistry, 2013, (USA)
28. Cantanhede RB, et al. Effects of water storage on bond strength and dentin sealing ability promoted by adhesive systems. J Adhes Dent 2012; 14:543-549.
29. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P. et al.: Adhesion to Enamel and Dentin. Operative Dentistry, 2003, 28(3):215-235
30. Blanchard PY, Kerbrat JB, Paulus C, Saint-Pierre F. Management of impacted cuspid –July 2015. Revue de Stomatologie, de Chirurgie Maxillo-faciale et de Chirurgie Orale, 2015;116 (6): 331-335
31. Hattar S, et al. Bond strength of self-adhesive resin cements to tooth structure. The Saudi Dental Journal. 2015; 27:70-74.
32. Cobanoglu N, Unlu N, Ozer FF, Blatz MB. Bond Strength of Self-etch Adhesives After Saliva Contamination at Different Application Steps. Operative Dentistry. 2013; 38(5): 505-511.
33. Mandava P, et al. Effect of moisture, saliva, and blood contamination on the shear bond strength of brackets bonded with a conventional bonding system and self-etched bonding system. J Nat Sci Biol Med. 2014; 5(1):123-129.
34. Oonsombat C, Bishara SE, Ajoluni R. The effect of blood contamination on the shear bond strength of orthodontic brackets with the use of a new self-etch primer. Am J Orthod Dentofacial Orthop. 2003; 123(5):547-550.
35. Sfondrini MF, Cacciafesta V, Scribante A, De Angelis M, Klersy C. Effect of blood contamination on shear bond strength of brackets bonded with conventional and self-etching primers. Am J Orthod Dentofacial Orthop. 2004; 125(3):357-360.
36. Kirihara M, Inoue G, Nikaido T, Ikeda M, Sadr A, Tagami J. Effect of fluoride concentration in adhesives on morphology of acid-base resistant zones. Dent Mater J. 2013; 32:578-584.
37. Mohd YA. Shear Bond Strength of Ceramic Brackets with Different Base Designs. Journal of Clinical and Diagnostic Research. 2016; 10(11):64-68.
38. Vera C. Use of micro-screws in the traction of retained maxillary canines. Rev. Estomatol. Altiplano 2017; 4(1):11-18
