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UDC: 616.314-089::616.314-089.23
DOI: https://doi.org/10.2298/VSP191206116S

Challenges, standards, and prospects in the therapy of orthodontic traction of impacted maxillary canine – A surgical phase

Izazovi, standardi i pravci razvoja terapije izvlačenja impaktiranog maksilarnog očnjaka – hirurška faza

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Key words:
adhesives; cuspid; oral surgical procedures; orthodontics; tooth, impacted.

Ključne reči:
adhezivi; očnjak; hirurgija, oralna, procedure; ortodoncija; zub, impakcija.

Introduction

The maxillary canine is the third tooth from the midline, positioned between the 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 of 13–15 [1, 2]. The 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 a 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 the population, with gender prevalence rates being 70% and 30% in females and males, respectively. The incidence of the palatal location of impacted maxillary canines is three times more frequent than that of labial location. In fact, 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 is an interceptive treatment in children with canines positioned palatal [8]. Therapy options include the following: 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 the 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 the 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 the surgical procedure, the tooth is uncovered from tissues, becoming visible in the oral cavity. The term “tooth liberation” is associated with the closed surgical

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technique in which the tooth remains invisible after the surgery. The method was first described by Hunt [9] and Mc Bride [10]. In case 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 is completed or if the tooth is improperly positioned, orthodontic traction management is required. In the 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 managing the 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 the tooth has not erupted after the expected optimal eruption time, while the same tooth erupted normally on the other side. The absence of the tooth (anodontia) and the exact position of the impacted tooth should be determined. Scan analysis identifies the position of the 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 a follicular cyst, odontoma and supernumerary teeth. Periapical radiography offers only basic information [12]. The position of the teeth was determined based on two images, the phenomenon of parallax, Clark's rule. Commonly, the term rule Buccal Always Moves Away (BAMA) 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 posteroanterior 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 the improvement of the therapeutic approach. Ericson and Kurol [13] defined the term "sector analysis" 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 the first premolar and first and second incisor. The position of the canine crown tip within a specific sector is determined. Moreover, the Ɵ-angle formed by the longitudinal axis of the canine tooth with interincisal line is defined. This analysis is vital for the prognosis of the success of the orthodontic traction procedure. The risk of root resorption of the lateral incisor is increased by some 50% if the canine is positioned in sectors 1 and 2 and with a Ɵ-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 [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 the surgical procedure in order to get an insight into the position of the tooth and surrounding tissue structures and estimate the appropriate position of traction appliances [19, 20]. Extremely rarely, the orthodontist might change his/her decision about the therapeutic approach during the first surgical tooth exposure. In that case, upon removal of tissue structures covering the crown, the orthodontist may decide that tooth extraction is highly indicated and informs the 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 [21]. The selection of relevant surgical procedures highly determines further treatment course. Open surgery has certain advantages, such as the presence of an orthodontist is not required, and 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 the case of closed surgery, the presence of an orthodontist is highly required [22, 23].

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 [24].

The advancements in the field of adhesives and composite materials enabled the placement of orthodontic brackets onto the impacted tooth. In the case of the 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 the opposite direction of tooth traction and has a tendency to break the bond between the tooth and orthodontic appliance. In case of bond failure, a 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 between the enamel and adhesive material, according to Miletić and Santini [25]. 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 a surgeon is a prerequisite for the successful outcome of this stage. Sometimes, persistent hemorrhage requires an application of pressure on the bleeding spot using a blunt instrument, bone wax, or cauterization. How to overcome the problem of conditioned enamel contamination and failure of the enamel-to-adhesive bond? Intraoperative placement of traction elements is complicated by humidity in the mouth cavity (saliva, blood), according to Varga and Šlaj [26]. After the removal of the acid and enamel drying, the adhesive is applied onto the tooth and light-polymerized. The majority of orthodontic adhesives used for bracket sealing are hydrophobic, i.e., their bond strength decreases significantly in a 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 the novel 7th generation monophase (self-etch) hydrophilic adhesives can substantially improve the tooth-to-adhesive bond strength in the presence of contamination [27]. A 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 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 s. The self-etching monocomponent adhesive removes potential moisture remaining from etched enamel. The adhesive is applied and allowed to penetrate for 20 s. This step is followed by polymerization for 20 s [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 a dry operating environment and fixing the brackets or chain with composite, whereas adhesive application itself is not considered a 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 et al. [29] in 2003. Two-step acid-etch adhesive is most commonly used. One-step self-etch adhesives are not widely used in everyday routines.

The answer to the question of whether to use monophase self-etching adhesive can be obtained only from an *in vitro* experiment [30, 31]. The use of extracted teeth enables simulation of specific conditions and measurement of shear bond strength. The majority of studies investigated the force applied at an angle of 90° (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 [32, 33]. Clearly defined protocols with guidelines for the 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 work protocol. 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 et al. [34] and Sfondrini et al. [35] pointed out the drop of shear bond strength associated with blood contamination. The authors also emphasized that the application of self-etch primers produces stronger bonds, which is due to hydrolysis that facilitates partial cleaning. The qualitative properties of 7th generation monophase self-etch adhesive systems have not yet been adequately investigated in a 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 [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 [37].

In closed surgery technique, where the 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 [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 a simpler alternative. Stainless steel wire is safe in the hands of both the orthodontist 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 potentially irreversible damage of periodontal tissues. Novel trends in orthodontics involve direct placement of 14 k gold chains [19] with small chain links that are gradually removed as the tooth erupts. In this way, the 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 the closed technique) should be small enough and low-height profile in order to produce minimum adverse effect on surrounding soft tissues.

Mini implants are increasingly used as an anchoring center when pulling impacted canines [38].

There is a growing trend to use mini implants in certain circumstances.

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. A team-based approach is indispensable. From the technical point of view, maximal concentration of both the 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 the enamel area. The chain should be covered with composite to minimize the resistive force of the tissue.

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Received on December 6, 2019
Revised on March 10, 2020
Accepted on November 4, 2020
Online First November, 2020