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An Individual Rapid Prototyping Attachment Used in Extrusion of Displaced and Transposed Maxillary Canine Tooth – Case Report

Zastosowanie diagnostyki 3D oraz szybkiego prototypowania w ortodoncji – opis własnej metody ekstruzji zatrzymanego kła

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A – research concept and design, **B** – collection and/or assembly of data, **C** – data analysis and interpretation,
D – writing the article, **E** – critical revision of the article, **F** – final approval of article

Abstract

Impacted or displaced maxillary canines are regarded as a significant clinical problem due to their esthetic and functional properties. The relatively high prevalence of such cases in the general population entails frequent management by practitioners. However, canine displacement combined with its transposition is a rare case that requires thorough diagnostic measures and an individually designed treatment plan. The purpose of this study is to present a methodology for management of a palatally displaced and transposed maxillary left canine based on cone-beam computed tomography (CBCT) imaging and rapid prototyping techniques. A 10-year old female patient with displaced and incompletely transposed upper left canine undergone thorough 3D orthodontic diagnostics involving creation of 3D anatomic STL models. Anatomic reconstructions were processed in rapid prototyping software and printed by means of 3D printing technology. Custom-designed attachment for orthodontic extrusion was milled from CoCr alloy on the basis of digital STL model accurately reflecting the anatomy of displaced canine. Despite difficult anatomic conditions, the tooth was successfully extruded with no complications regarding the adjacent teeth. CBCT is not only an efficient tool for multi-planar assessment of dental abnormalities and the facial skeleton, but it also allows for the creation of 3D models of the patient's anatomy enabling the computer aided design individual treatment solutions (**Dent. Med. Probl. 2014, 51, 1, 119–129**).

Key words: canine displacement, dental transposition, rapid prototyping, cone-beam computed tomography.

Streszczenie

Stożkowa tomografia komputerowa (cone-beam computed tomography – CBCT) zyskuje coraz większe znaczenie w diagnostyce ortodontycznej. Możliwość uwidocznienia struktur twarzoczaszki w dowolnej projekcji pozwala na dogłębną ocenę anatomii także w przypadku asymetrycznych zaburzeń oraz dokładne określenie położenia zatrzymanych zębów. Ważnym poszerzeniem możliwości diagnostycznych skanu CBCT jest konwersja danych do postaci trójwymiarowej wizualizacji tkanek pacjenta. Tak otrzymany wirtualny model może służyć nie tylko do realistycznej oceny stosunków anatomicznych, ale przede wszystkim podlegać modyfikacjom umożliwiającym zindywidualizowanie postępowania terapeutycznego. W pracy przedstawiono przypadek 11-letniej pacjentki z zatrzymanym górnym lewym kłem. Na podstawie skanu CBCT przygotowano model 3D szczęki pacjentki oraz zatrzymanego zęba. Następnie z wykorzystaniem specjalistycznego oprogramowania stworzono wirtualny model zaczepu w taki sposób, aby stanowił idealny negatyw powierzchni podniebiennej mającego podlegać ekstruzji zęba. W kolejnym etapie wirtualny model przekształcono w prototyp z fotopolimeru, ten zaś zamieniono na stop chromo-kobaltowy w pracowni technicznej. Tak otrzymany zaczep charakteryzował się: wyprofilowaniem dopasowanym do powierzchni zęba pacjentki, zwiększeniem powierzchni adhezyjnej, znacznie poprawioną retencją w stosunku do standardowo stosowanych guziczków, co umożliwiło skrócenie czynności klinicznych oraz efektywną ekstruzję zatrzymanego kła (**Dent. Med. Probl. 2014, 51, 1, 119–129**).

Słowa kluczowe: zatrzymane kły, transpozycja zębów, techniki szybkiego prototypowania, stożkowa tomografia komputerowa.

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Due to their relatively high prevalence in the general population – 1–3% [1] or 0.9%–2% [2], impacted maxillary canines are considered a challenging clinical problem. They rank behind mandibulary and maxillary third molars as the most frequently impacted group of teeth [1, 3], while the functional and esthetic role of a fully erupted canine cannot be overestimated. Traditionally, palatal impaction of maxillary canines was considered to occur 2 to 3 times more frequently than buccal impaction [4, 5]; however, more recent MSCT/ /CBCT studies suggest that their frequencies of occurrence are very similar; mid-alveolar impactions are identified in only 18 percent of cases [6, 7]. The presence of a long root, which contributes to the fundamental occlusal functionality of canines, is also considered a factor responsible for a long eruption path which could result in various complications affecting tooth position, such as impaction/displacement or transposition [8]. It is important to differentiate between dental displacement and impaction – both phenomena involve incorrect, infraosseus tooth position, however, impaction can be only diagnosed when the tooth remains unerupted after the expected, physiological eruption time. Displacement can be identified before that period; most palatal canine displacements result in impactions [9].

Dental transposition is considered a sub-type of ectopic eruption; a phenomenon which could be defined as interchange of position in the dental arch of two adjacent teeth or the development of a tooth in a location normally occupied by a non-adjacent tooth [10]. Transpositions most often involve maxillary canines and first premolars; however, canines and lateral incisorsare are also involved in fewer cases [11]. The development of a canine tooth in the site of the first molar, transposition involving central and lateral incisors and ectopic eruption of canine in the locus of central incisor are also possible [11]. The prevalence of dental transposition is generally low 0.4% [12] and in most cases, the canine and first premolar are involved: in 0.03% of Swedish schoolchildren [3], 0.13% of Arabian dental patients [13] and 0.25% of Scottish orthodontic patients [14]. Possible complications connected with the impaction and ectopic position of canines are root resorption of adjacent teeth structures, ankylosis and follicular cyst formation and crown resorption of impacted canine itself [7, 15–18]. Orthodontic eruption of the impacted canine after surgical exposure and moving the affected tooth in its normal position is the most desirable course of action, especially when the transposition is not complete i.e. it involves only the coronal portions of the tooth. Other treatment options involve autotransplantation of the impacted canine, extraction with or without retaining the deciduous predecessor and subsequent orthodontic space closure, or prosthetic treatment by means of a fixed bridge or an implant [19].

The accurate identification of impacted tooth position is vital to the course of treatment. Computed tomography imaging (CT), particularly cone-beam computed tomography, allows the 3-dimensional assessment of impacted canine position [20] and the detection of any abnormalities and complications that could impair the treatment progress, particularly the resorption of adjacent teeth. The advantages of CBCT over CT are apparent in dental imaging: significantly lower radiation dose [21, 22], increased image resolution and volumetric character of acquired data is among the most significant examples. The limited field of view of most CBCT scanners does not limit its capabilities in diagnosing dentoalveolar abnormalities. Furthermore, the DCM (dicom) files from CBCT can be converted into 3-dimensional models that could improve diagnosis accuracy and can be further processed by means of rapid prototyping software if saved in STL file format. As mentioned by Faber et al. [23], the diagnostic possibilities offered by a CBCT scan exceed those associated with the evaluation of 3D anatomical reconstructions on a computer screen but also allow for „actual 3D" assessment of patient anatomy via resin prototypes manufactured by additive techniques.

The aim of this study is to present a diagnostic methodology and management of a complex case of palatally displaced and incompletely transposed maxillary canine which involved manufacturing of rapid prototyping anatomic models and individually designed and milled from CoCr alloy attachment used for orthodontic extrusion.

Case Report

A female patient, 10 years and 8 months old, was referred to the Orthodontic Department for orthodontic consultation regarding the anterior maxillary region. The main complaint was the incorrect tooth spacing and the malpositioned lateral left incisor (tooth 22), which was distally translated and rotated (Fig. 1). Extra-oral examination showed a slightly convex profile with good facial symmetry (Fig. 1). Intra-oral examination showed the visible cusp of an erupting right canine with no similar symptoms on the other side of the maxilla where the position of tooth 23 was occupied by tooth 22 (Fig. 1). No submucosal protruberance could be palpated on either the buccal or palatal side in the left canine region. The patient present-

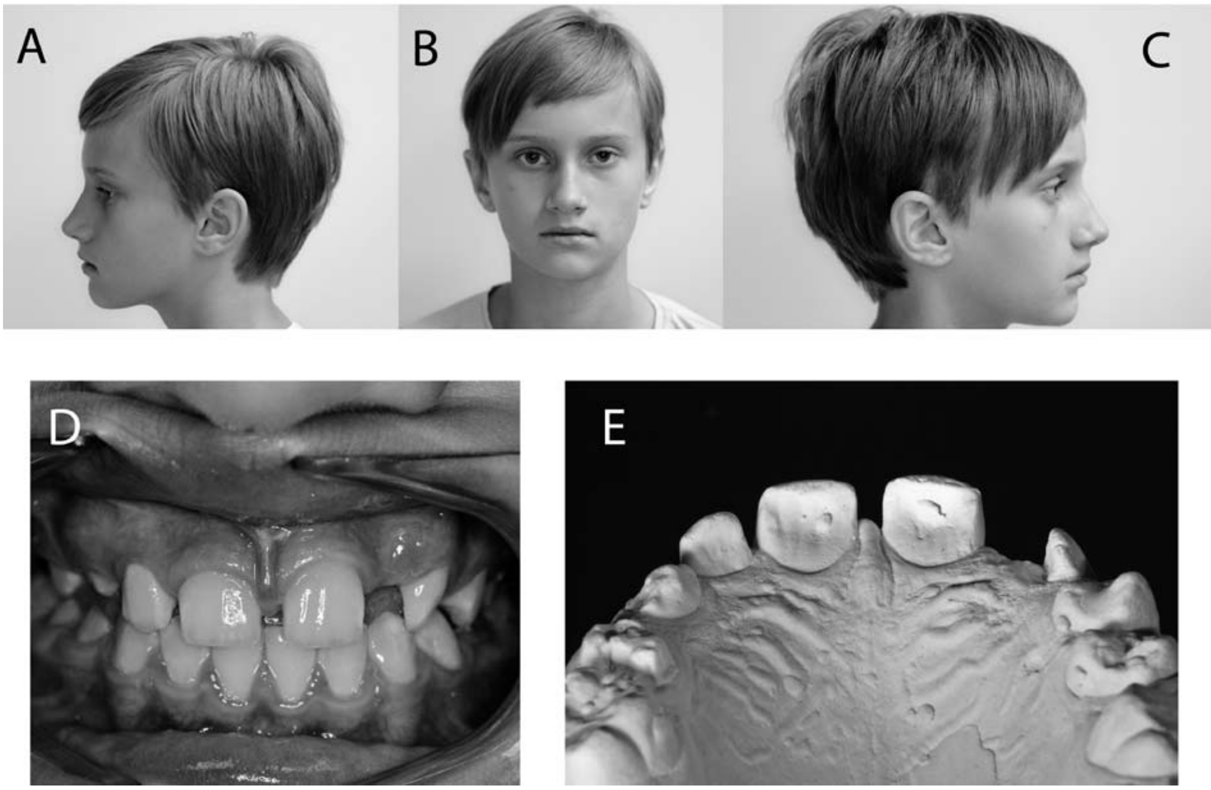

Fig. 1. Patient's profile: a) left, b) upfront, c) right view. Intra-oral conditions before the treatment onset as clinically seen d) and on a plaster cast e)

Ryc. 1. Rysy twarzy pacjentki: a) widok od lewej strony, b) na wprost, c) od prawej strony. Warunki wewnątrzustne przed rozpoczęciem leczenia widoczne w badaniu klinicznym d) oraz na modelu gipsowym e)

ed pseudo-II Angle class inter-cuspidation on the right side due to the mesial drift of tooth 16 caused by the premature loss of deciduous molars. On the left side I Angle class was diagnosed; no midline deviation was observed. General medical history was not relevant; cephalometric examination indicated I skeletal class.

Diagnosis and Treatment Plan

A panoramic radiograph was taken to identify the position of the maxillary left canine and the possible cause of the distal translation of tooth 22 (Fig. 2). The radiograph revealed that the intraosseus position of tooth 23 was displaced, with its crown directed towards the root of the central left incisor; however, the tip of the canine root was in the correct location. The lateral left incisor was positioned in the site of tooth 23. To validate the initial diagnosis of left maxillary canine displacement with canine-lateral incisor, an incomplete transposition limited field of view CBCT scan was performed of the maxillary region. A Gendex GXCB-500 device was used with voxel size set at 0.125 mm at 120 kV and 5 mA, resulting in the highest possible resolution (KaVo Dental GmbH, Biberach/Riß, Germany). The CBCT examination allowed for an accurate multi-planar examination of the tooth involved (Fig. 2). The canine was found to be displaced palatally with the tip of its cusp in the direct proximity of the central incisor root. No signs of root resorption were found on the adjacent tooth 21; the follicle of displaced 23 was qualified as normal, no signs of ankylosis or cervical resorption were identified. The observed transposition was qualified as incomplete, as only the coronal portion of tooth 23 was malpositioned, being tilted towards the midline and anterior region. As the volumetric data of the CBCT scan was stored in dicom file format, it was possible to obtain a 3D reconstruction of the area. All 479 slices obtained were opened in 3D Doctor 4.0 software (Able Software Inc.) and underwent interactive segmentation, with thresholds set at > 915 HU (Hounsfield units) for hard dental tissues and values between 120 HU and 915 HU for compacted bone tissue. Data representing soft tissues was not segmented. The obtained 3D reconstructions, separate 3D models for teeth 21, 22 and 23 as well as one for the maxilla without the aforementioned teeth, were exported in.stl mesh format and processed in VisCAM Mesh 5.2. rapid proto-

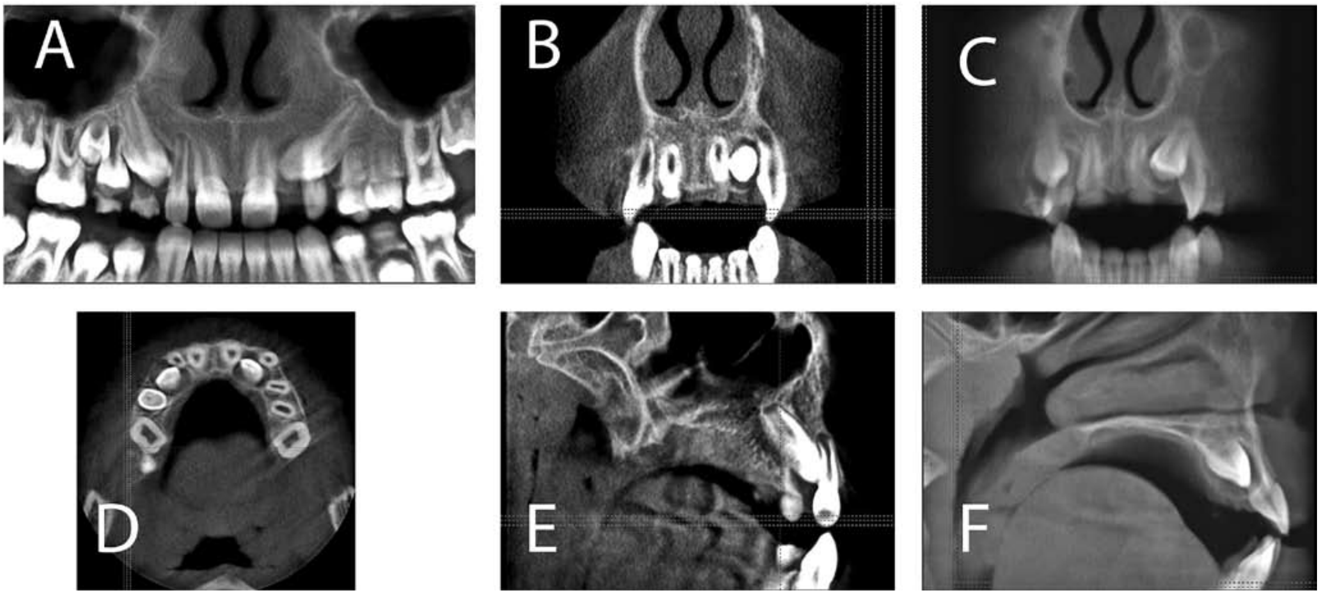

Fig. 2. Radiographic examination results: a) orthopantomogram; b), c) frontal projections exported from CBCT scan; d) horizontal projection exported from CBCT scan; e), f) sagittal projections exported from CBCT scan

Ryc. 2. Wyniki badań obrazowych pacjentki: a) zdjęcie pantomograficzne; b), c) wyeksportowana z CBCT projekcja w płaszczyźnie czołowej; d) wyeksportowana z CBCT projekcja w płaszczyźnie poziomej; e), f) wyeksportowana z CBCT projekcja w płaszczyźnie strzałkowej

typing software (Marcam Engineering GmbH, Bremen, Germany). The 3D models of 21, 22, 23 and the maxilla after mesh adjustment and refinement are presented in Fig. 3. This visualization not only improved the understanding of the relations between adjacent teeth, impacted tooth and the surrounding bone, but also aided in treatment plan creation. The treatment plan comprised of following stages:

1 – surgical exposure of the displaced canine by close-flap procedure,

2 – bonding of the individual attachment used for forced orthodontic extrusion to the transversal palatal arch,

3 – the guided eruption of the impacted canine in the distal direction,

4 – restoration of space for tooth 23 by translating the left central and lateral incisors towards the midline by means of the straight wire technique,

5 – space restoration for tooth 15.

Treatment plan stages 1–5 were validated by a virtual setup on STL 3D models and accepted by parents and a patient (Fig. 4).

Attachment and Resin Model Manufacture

The attachment for orthodontic extrusion was individually designed and manufactured based on a number of factors: the difficult anatomic conditions and deep intraosseous position of the impacted canine crown; the necessity to bond the attachment to the palatal surface of the canine with many irregularities that could impair the bonding strength of standard attachments; the patient's young age, resulting in the limited compliance during the surgical procedure; the need for perfect alignment of the attachment to the palatal surface of the canine for increased bonding strength; finally, the possibility of attachment profiling to allow the crown portion of canine to be tipped distally during forced eruption.

The mesh STL model of attachment can be seen in Fig. 6. It was designed in rapid prototyping software, exported into a Ceramill software suite and milled from a CoCr alloy block by a Ceramill Motion device (AmannGirrbach, Koblau, Austria). Virtual models of the teeth 21, 22, 23 and the maxilla were obtained by 3D printing technology (PRO JET DP3510, 3dSYSTEMS, Rock Hill, SC, USA) and served as a 3-dimensional anatomic guide for the surgeon (Fig. 7). Resin prototypes were specifically prepared so that teeth could be inserted into the maxilla model or assessed individually. A milled attachment was prepared to remove any sharp edges and reduced in size so it could be easily bonded during surgery (Fig. 7). When aligned to the palatal surface of the resin prototype, the milled custom attachment was found to fit perfectly (Fig. 6). The surface of the attachment was activated by sandblasting and cleaned with isopropanol.

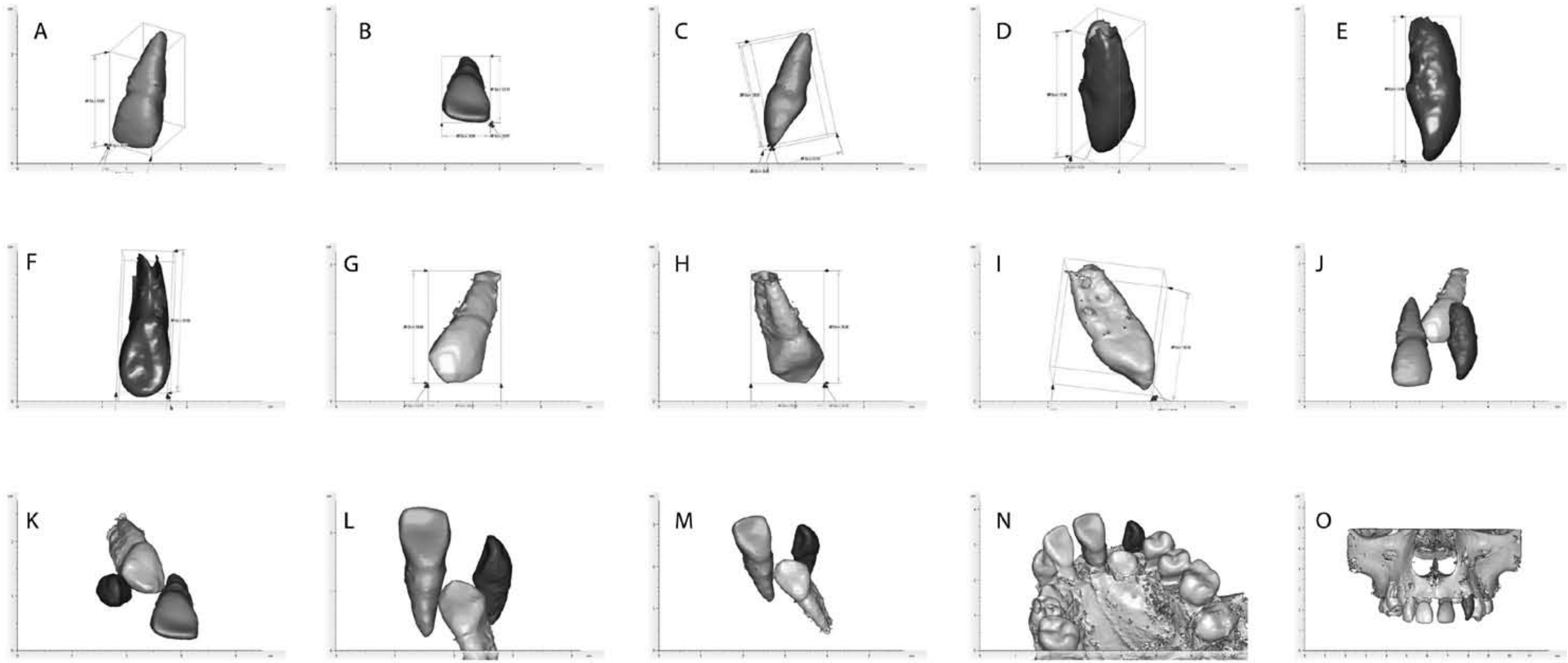

Fig. 3. 3-dimensional anatomic reconstructions of teeth involved in the abnormality: a–c) tooth 21; d–f) tooth 22; g–i) tooth 23; j–m) spatial anatomic relations between the teeth 21, 22, 23; n–o) anatomic reconstructions of maxillary region

Ryc. 3. Trójwymiarowa rekonstrukcja stosunków anatomicznych okolicy zaburzenia: a–c) ząb 21; d–f) ząb 22; g–i) ząb 23; j–m) przestrzenne relacje anatomiczne między zębami 21, 22, 23; n–o) rekonstrukcja anatomii szczęki

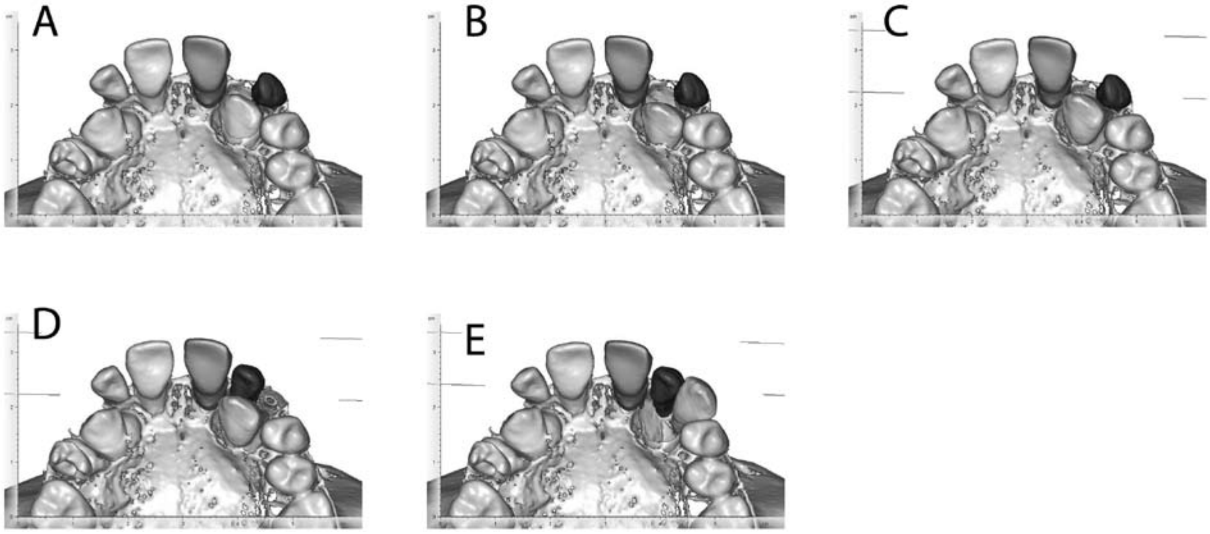

Fig. 4. Virtual setup of desired treatment progress: a) tooth 23 extruded in distal direction; b), c) continued orthodontic extrusion of tooth 23; d) space restoration for tooth 23; e) tooth 23 introduced into dental arch

Ryc. 4. Wirtualny setup (symulacja) pożądanego przebiegu terapii: a) ząb 23 ekstrudowany w kierunku dystalnym; b), c) dalsza ekstruzja zęba 23; d) odtwarzanie miejsca dla zęba 23; e) ząb 23 wprowadzony do łuku zębowego

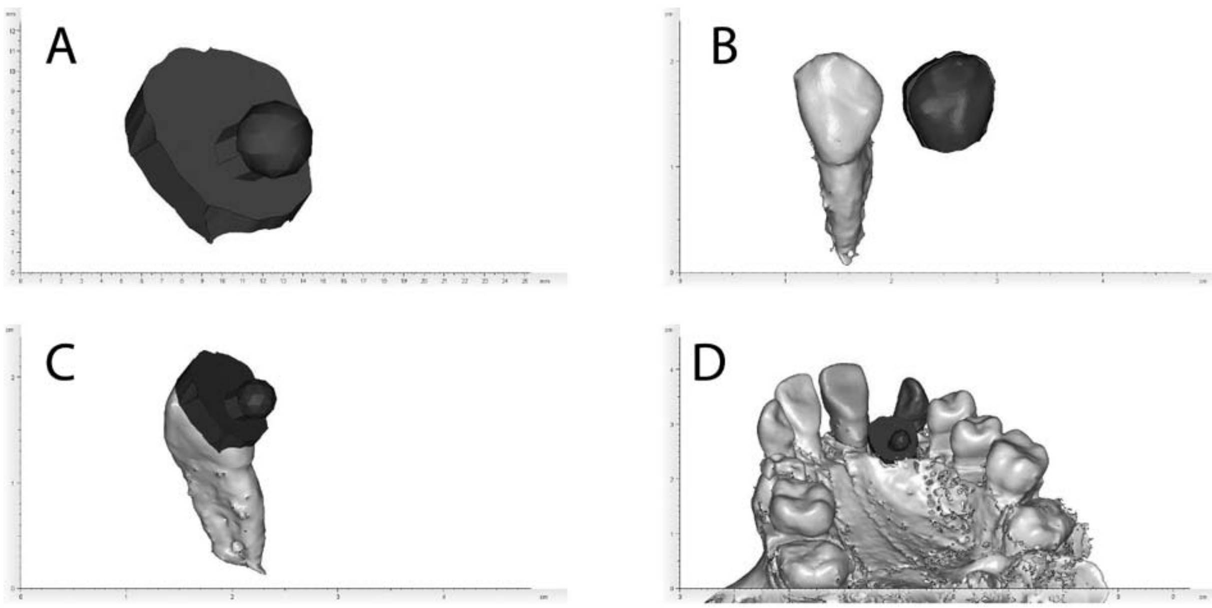

Fig. 5. STL mesh models of: a) custom attachment; b) tooth 23 and custom attachment; c) custom attachment fitted on tooth 23; d) anatomic reconstruction of maxillary area with the attachment fitted on tooth 23

Ryc. 5. Cyfrowe modele 3D: a) indywidualnego zaczepu; b) zęba 23 oraz indywidualnego zaczepu; c) indywidualnego zaczepu dopasowanego do powierzchni zęba 23; d) rekonstrukcja anatomii okolicy szczęki wraz z zębem 23 oraz dopasowanym zaczepem

Treatment Progress

Of all recommended surgical methods, the closed-flap technique is considered to have the best long-term prognosis, especially when impaction is deep within the alveoulus [24]. The mucoperiosteal flap was separated from the palatal region of canine displacement. An underlying bone strip of 2–3 mm wide surrounding the crown portion of tooth 23 was removed with a bur equipped with water-spray cooling, and an area of the palatal surface of the crown sufficient for bonding individual attachment was exposed (Fig. 8). Subsequently, the crown of the canine was rinsed with 0.9% saline

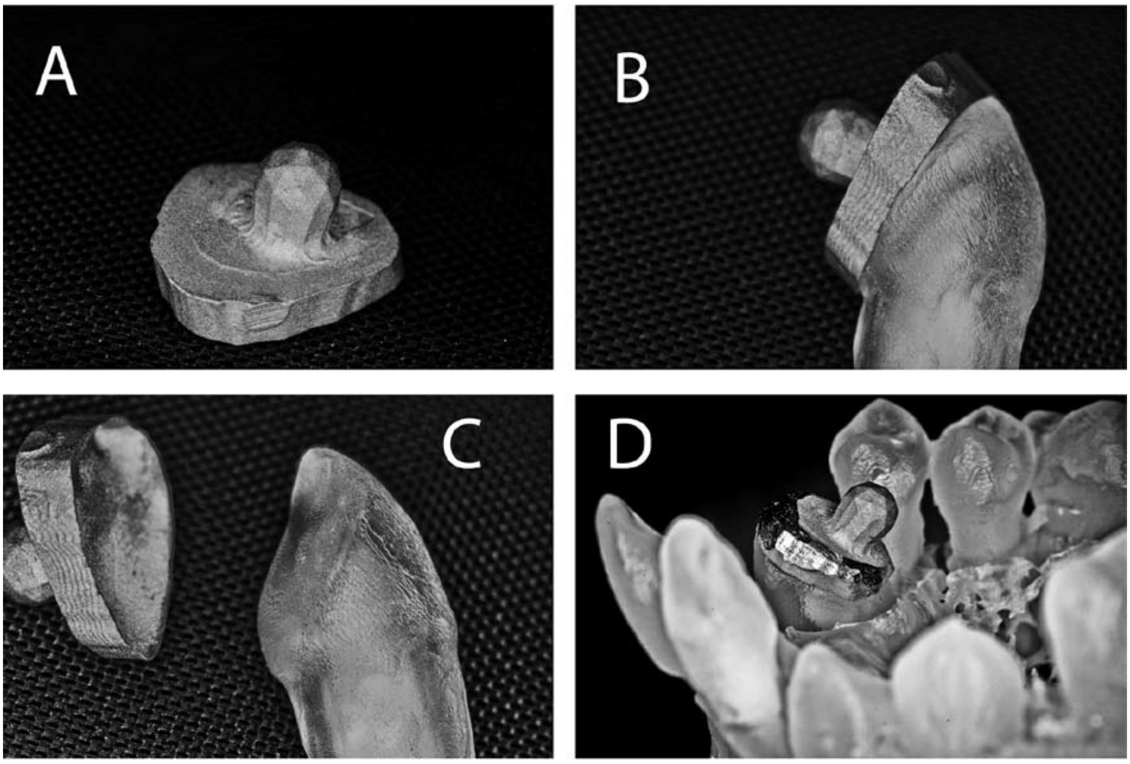

Fig. 6. Rapid prototyping models used for case management: a) milled CoCr custom attachment, b) CoCr attachment fitted on the resin, 3D-printed model of tooth 23; c) bonding surface of attachment perfectly reflects the anatomy of palatal surface of tooth 23; d) prepared attachment fitted on resin model of the tooth 23 inserted into resin prototype of maxillary region

Ryc. 6. Modele uzyskane techniką szybkiego prototypowania użyte w czasie terapii: a) wyfrezowany indywidualny zaczep ze stopu CrCo, b) indywidualny zaczep ze stopu CrCo dopasowany do polimerowego modelu zęba 23 uzyskanego techniką drukowania 3D; c) powierzchnia kontaktu zaczepu doskonale odzwierciedla anatomię podniebiennej powierzchni zęba 23; d) indywidualny zaczep dopasowany do polimerowego modelu zęba 23 włożonego do polimerowego prototypu szczęki

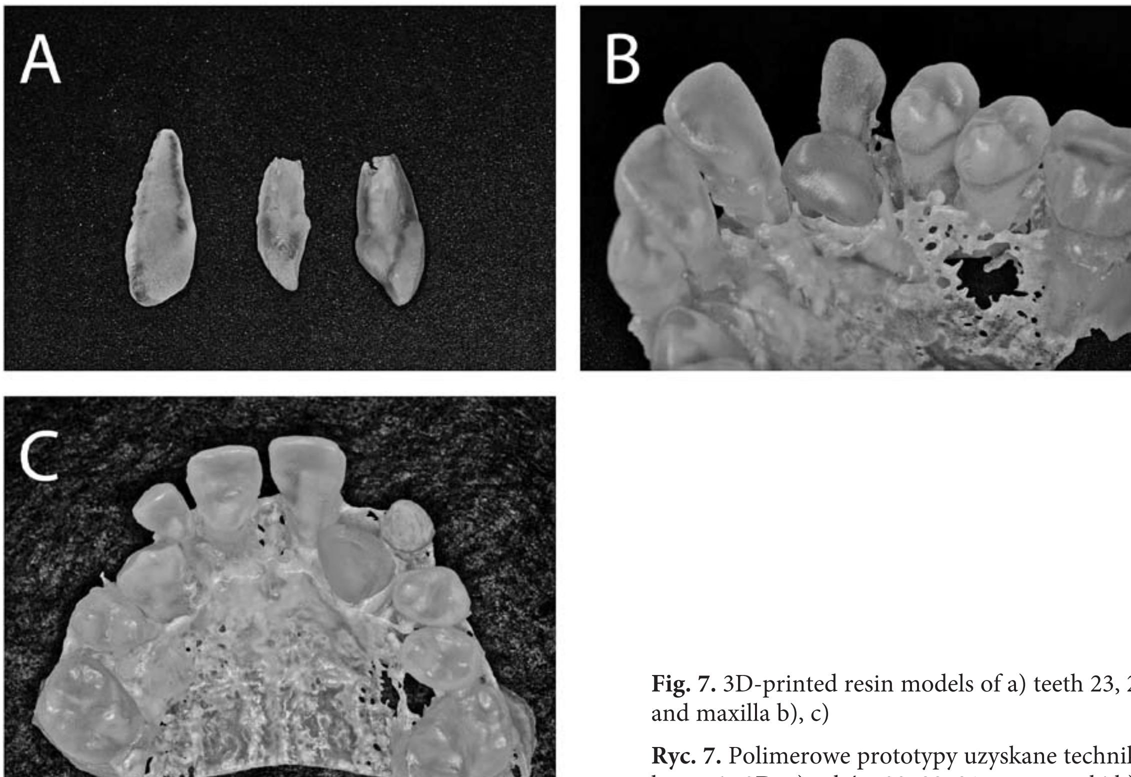

Fig. 7. 3D-printed resin models of a) teeth 23, 22, 21 and maxilla b), c)

Ryc. 7. Polimerowe prototypy uzyskane techniką drukowania 3D: a) zębów 23, 22, 21 oraz szczęki b), c)

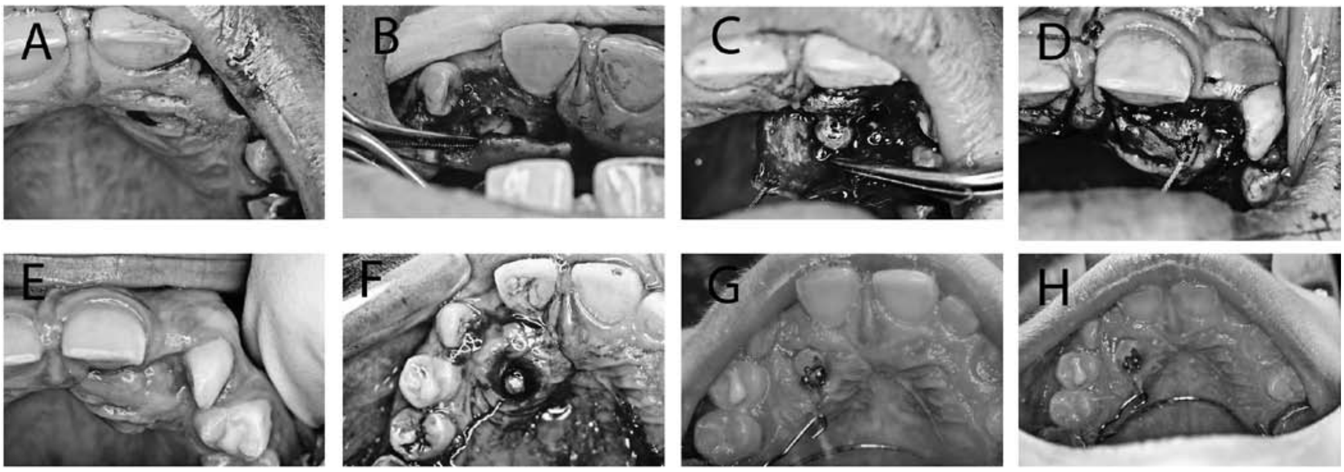

Fig. 8. Treatment stages and progress: a) before the surgical procedure; b) tooth 23 visible under the retracted mucoperiosteal flap; c) custom attachment positioned on exposed tooth to check whether the exposure area is sufficient; d) mucoperiosteal flap repositioned and resutured over the cemented attachment; e) 2 weeks after the surgery, proper wound healing; f) surgically exposed attachment's head connected with fishing-rod like appliance by means of NiTi ligation wire; g) 10 weeks after the traction onset; coronal portion of canine is visible over the mucosa margin; custom attachment was replaced with conventional bracket; h) 18th week of traction – orthodontic extrusion progresses as planned

Ryc. 8. Przebieg poszczególnych etapów terapii: a) warunki przed rozpoczęciem zabiegu chirurgicznego; b) ząb 23 widoczny pod odsuniętym płatem śluzówkowo-okostnowym; c) indywidualny zaczep umieszczony na odsłoniętym zębie 23 w celu sprawdzenia, czy powierzchnia odsłonięcia jest wystarczająca; d) płat śluzówkowo-okostnowy po repozycji nad zacementowanym zaczepem i ufiksowaniu za pomocą szwów; e) stan po 2 tygodniach od zabiegu; widoczne prawidłowe gojenie rany; f) odsłonięta chirurgicznie główka zaczepu połączona z grubołukowym zaczepem w kształcie "wędki" za pomocą drutu ligaturowego ze stopu NiTi; g) stan po 10 tygodniach od rozpoczęcia ortodontycznej ekstruzji zęba 23; część koronowa zęba widoczna powyżej granicy błony śluzowej; na tym etapie indywidualny zaczep został zastąpiony standardowym metalowym zamkiem ortodontycznym; h) 18 tydzień ortodontycznej trakcji – terapia przebiega zgodnie z planem

solution and was carefully dried with air and sterile cotton pellets. The enamel was etched with 40% phosphoric acid for 60 s, then carefully removed with 0.9% saline and cotton pellets. The bonding surface was covered with Excite F (IvoclarVivadent, Schaan, Liechtenstein) bonding agent and light-cured for 20 s. Due to its relative insensitivity to moisture self-curing, Evicrol composite (SpofaDental, Jičín, Czech Republic) was chosen as a luting agent. Enhanced alignment to the exposed tooth surface of individual attachment allowed for easy positioning and shortened the procedure despite the difficult conditions (Fig. 8).

After successful fixation of the attachment, the flap was repositioned and re-sutured (Fig. 8). At the next appointment, 2 weeks later, the healing of the wound was inspected and the sutures removed (Fig. 8). A small incision was made to expose the head of the attachment. NiTiwire ligature was then positioned on the incision and fixed to the orthodontic band cemented on the upper left first molar (Fig. 8). The initial intention to use an elastic chain for the orthodontic procedure could not be realized until the next visit as the patient's initial compliance was poor. An elastic chain attached to an appliance resembling a fishing rod fixed to the passive transversal palatal arch cemented on first molars was placed on the head of the attachment during the next appointment. A 60 g traction force was set. After 10 weeks of active traction, with the elastics replaced every 2 weeks, the canine cusp was visible above the line of mucosa (Fig. 8). At this stage, the custom attachment was replaced with a conventional bracket which was significantly smaller and more comfortable. Treatment was continued with the same schedule of examinations. Treatment progressed as planned through 18 week of active traction. On the 22th week, the treatment plan moved on to restoring space for the erupting canine by means of straight wire technique and introducing it to the dental arch.

Discussion

Canine impaction combined with incomplete canine – lateral transposition – is considered a relatively rare occurrence. Although the cases of partial transposition are easier to manage than complete dental transposition due to the proper root apex location, they still require careful and accurate execution of the treatment plan. The possibility of adjacent tooth root resorption, alveolar bone loss, periodontal complications and temporary occlusal interference needs to be taken into consideration as does the projected duration of long-term therapy [25]. Tooth transposition is considered to be accompanied by other dental anomalies such as hypodontia, peg-shaped teeth, severe discrepancies in adjacent tooth position, retention of deciduous dentition, dilacerations and other malformations of dental hard tissues [12, 26–28]. Although lateral maxillary incisors of the patient described herein could not be defined as peg-shaped, according to Becker et al. [29] definition, the widest diameter of such tooth's crown should be at its cervical margin, they are not of a typical size and shape, being very narrow and slightly cone-shaped. Furthermore, dental transposition is considered to occur more often in females and in the left maxillary region [12, 28]. Hence, among the theories attempting to explain the etiology of transposition, the multifactorial inheritance model has the most support (27.30). Local disturbances such as intraosseous migration of the canine [31], trauma to the deciduous predecessor [32], the presence of cysts [33] and retained deciduous canine have also been proposed as a possible explanation. It may be that both genetic and environmental factors play certain roles in the occurrence of dental transposition [34]. The present patient had no history of dental trauma, and no other intra-osseous abnormalities were observed.

According to Peck and Peck [11], cases of incomplete transposition should be considered as ectopic eruption rather than transposition. However, most authors include cases of incomplete transposition in their studies concerning dental transpositions [12, 34, 35]. Contrary to labial canine impactions, palatal canine impaction/ /displacement is not usually related to the lack of space in the dental arch [36], and other causes are involved. The guidance theory considers the root of lateral incisor as a guide for erupting canine. Should the lateral incisor's root be malformed or absent, the canine will not be able to erupt properly [37]. As mentioned earlier, the shape of the present patient's lateral incisor was slightly different, which may explain the canine displacement. It does not, however, explain the unilateral character of observed disturbance. Among other theories, endocrine systemic disorders and genetic etiology are the most significant [6, 8, 38]. Some authors note a relationship between palatal canine impaction and the presence of enamel hypoplasia, infraocclusion of primary molars, aplasia of second premolars and small maxillary lateral incisors [38]. None of this phenomena can be observed in the present case. Due to its limited radiological exposure in comparison with conventional CT, imaging accuracy and volumetric data characteristic [20, 39] cone-beam computed tomography has altered the diagnostic approach to complex cases of dental anomalies and discrepancies on many levels. Firstly, it allows 3-dimensional evaluation of anatomy and inspection for intra-osseous pathologies to be performed. Traditionally applied radiographs, such as dental X-rays, orthopanthomograms and lateral cephalograms, even when combined, may not identify 50% of root resorption cases [16, 40, 41]. According to Bjerklin and Ericson [6], CT/CBCT examination altered the initial treatment plan in 44% of cases due to new findings regarding the presence of tooth resorption. Firstly, an orthopantomogram is often burdened with significant image distortion in the canine area [41]. Secondly, the degree of realism regarding the dimensions and the resolution of the smallest anatomic details allow 3-dimensional anatomic reconstructions to facilitate more effective assessments of clinical problems: depending on the scan settings, voxel size can be as small as 0.06 mm. Such models can be rotated and translated according to the wish of the clinician, thus reducing the role of time consuming, conventional setups. In the present case, 3D reconstructions improved management by confirmation of initial diagnosis and intuitive presentation of spatial anatomic conditions, accurate location of ectopic tooth, exclusion of the presence of adjacent teeth resorption, planning desired tooth movement sequence, virtual set-up creation and finally, manufacturing the individual attachment. A similar methodology of manufacturing custom attachment was proposed by Faber et al. [23]. However, there are certain differences that need to be mentioned. For the purpose of our study, a CBCT scan was performed, resulting in improved imaging quality (0.125 mm isotropic voxel) and decreased radiation exposure in comparison with helical Multi-Slice CT. While a CBCT scan can be treated as a diagnostic method of choice in older adolescent patients, especially in complex cases, the role of MSCT in Dentistry is diminishing: the application of the workflow proposed in our study does not require extra-ordinary diagnostic measures. STL models created for management of our case represented both bone and dental tissues so that both interdental and tooth-bone anatomic relations were apparent. The amount of bone covering the impaction is particularly important for the practitioner during the planning of tooth exposure surgery. Similarly, the rapid prototyping models were designed and manufactured to meet the expectations of the orthodontist and the surgeon by providing data concerning the orientation of the roots involved in the abnormality and the amount of bone. Resin-prototype teeth could be removed from the maxilla prototype and inspected. When inserted in the prepared "sockets", the whole resin model could be handled like a plaster cast. Although it did not provide any information concerning soft tissue contours, its main advantage was clear identification of the location of the displaced canine.

According to the literature, the use of rapid prototyping models as an anatomic guide can decrease surgery time and improve its outcome in significantly more complicated cases [42]. The total cost of all resin models printed for the management of this particular case was € 25, not including the price of a custom-milled CoCr attachment, which was € 18. The attachment was milled directly on the basis of its virtual model. Computer aided milling was chosen over conventional casting to diminish the risk of possible inaccuracies and to take full advantage of the exceptionally precise scanning and 3D printing method. Although the manufacture of resin prototypes and custom-milled attachments may not be justified in every case, mainly due to its relatively high cost, such bespoke attachments have clear advantages in more complex cases where patient compliance is not satisfactory, surgery time needs to be as short as possible and treatment mechanics need to be accurately executed.

The authors concluded that cone-beam computed tomography, apart from significantly improving the diagnostic process of complex orthodontic cases, allows for the introduction of 3-dimensional design methodology into their routine management. The creation of complex anatomic 3D models and fabrication of individual, precise treatment solutions in Orthodontics is clinically applicable due to the development of rapid prototyping and CAD/CAM techniques. The manufacture of custom-designed attachments allowed for successful forced eruption of a displaced and incompletely transposed maxillary canine, and 3D-printed resin models improved the communication with the surgeon and patient.

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