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a three-year follow-up case report**

**Gecikmiş Diş Replantasyonunda Soğuk Atmosferik Plazma:
Üç Yıllık Takipli Bir Olgu Sunumu**

Avulsed tooth delayed replantation

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Esra BALKANLIOĞLU: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration.

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Abbreviations

Cold atmospheric plasma: CAP
Mineral trioxide aggregate: MTA
Preferred Reporting Items for Case reports in Endodontics: PRICE
Periodontal ligament cells: PDLc

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ABSTRACT

Tooth avulsion followed by delayed reimplantation presents a high risk of infection and root resorption. This report describes a 13-year-old boy who presented 24 hours after trauma involving avulsion of the left maxillary central incisor and a complicated crown fracture of the right incisor. The avulsed tooth, stored in milk, was treated with sodium fluoride and cold atmospheric plasma before reimplantation, while the fractured tooth received MTA partial pulpotomy. Clinical and radiographic follow-ups at three months, one year, and three years showed no ankylosis or resorption, and both teeth remained functional. Cold atmospheric plasma may enhance antimicrobial control and support periodontal healing in delayed reimplantation cases.

Keywords: Avulsion; Cold plasma; Crown Fractures; Delayed Reimplantation; Vital Pulp Therapies

ÖZET

Gecikmiş diş replantasyonu, enfeksiyon ve kök rezorpsiyonu açısından yüksek risk taşıyan karmaşık bir dental travmadır. Bu olgu sunumu, travmadan 24 saat sonra başvuran 13 yaşındaki bir erkek hastada sol üst santral diş avülsiyonu ve sağ üst santralde komplike kron kırığını içermektedir. Sütte saklanan avülse diş, replante edilmeden önce sodyum florür ve soğuk atmosferik plazma ile işlem görmüş; kırıklı dişe MTA ile parsiyel amputasyon uygulanmıştır. Üç ay, bir yıl ve üç yıllık klinik ve radyografik takiplerde ankiloz veya rezorpsiyon izlenmemiş, her iki diş fonksiyonel kalmıştır. Soğuk atmosferik plazma, gecikmiş replantasyon olgularında iyileşmeyi destekleyebilecek bir yardımcı yöntem olabilir.

Anahtar Kelimeler: Avülsiyon; Soğuk Plazma; Kron Kırıkları; Gecikmiş Reimplantasyon; Vital Pulpa Tedavileri

Introduction

Traumatic injuries of the permanent anterior teeth are frequent and may cause pulp damage and periodontal injuries, such as avulsion. Avulsion, a periodontal injury, is the complete departure of a tooth from its socket and requires special care.¹ The ideal treatment for avulsed permanent teeth is immediate replantation within 20-30 minute (min) after trauma.² However, immediate replantation of avulsed teeth may not always be possible.

Another type of dental traumatic injury is complicated crown fracture. Treatment strategies differ based on the duration between trauma and treatment, the condition of the pulp tissue, stage of tooth development, and size of exposure.³ Vital pulp therapies are more advantageous than others, providing less invasive treatment and/or restoration.

Cold plasma, a state of matter with a partially ionized gas, has emerged as a promising therapeutic agent in the field of dentistry. A plasma jet device is designed to produce reactive particles, including electrons, ions, and oxygen radicals, by utilizing a combination of gases, typically composed of argon, helium, air, nitrogen, oxygen, and electric energy. Bacterial destruction is caused by the interaction of reactive particles with their membranes. Plasma technology is versatile in the biomedical field, encompassing applications such as sterilization, wound healing, growth factor stimulation, tissue regeneration, and tumor cell death.⁴ The use of cold plasma in dentistry is suggested for various reasons, including bonding to dentin and ceramics, surface activation of dental implants, bleaching, curing of composites, and antimicrobial therapy for caries, periodontics, endodontics, and implantology.⁵

The objective of this case report is to present the delayed replantation of a maxillary central incisor that was avulsed, along with the application of cold plasma and the partial pulpotomy of another incisor with a complicated crown fracture 24 h after trauma.

Case Report

This case report has been written according to Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 guidelines (Figure 1).⁶



Figure 1: Price flowchart.

Anamnesis of the patient

A 13-year-old Turkish boy was referred to the endodontic clinic because of a fall, with the chief complaint of fracture and loss of teeth. The avulsed tooth was placed in cold milk at 15th min of extra-oral dry

time by the patient's parents. The duration between tooth avulsion and referral was 25 h. There was no known systemic disease according to family information.

Examination of the patient

Extraoral examination revealed no signs of injury or fracture of the nasomaxillary complex. Intraoral examination revealed avulsion of the left maxillary central incisor (tooth 21). The right maxillary central incisor (tooth 11) had a complicated crown fracture, pulp damage, and slight mobility (Figure 2). Panoramic and periapical radiographs (Planmeca, Helsinki, Finland) revealed no broken teeth or bony segments in the surrounding tissues (Figure 3). Clinical examination revealed no signs of soft tissue laceration, swelling, or infection. Radiographic evaluation demonstrated complete root formation with closed apices and no evidence of root fracture, alveolar bone fracture, or pre-existing periapical pathology.



Figure 2. Avulsion of the left maxillary central incisor (tooth 21). The right maxillary incisor (tooth 11) had complicated crown fracture, pulp damage, and slight mobility.



Figure 3. Intraoral periapical radiographs

Treatment of the patient

The actual treatment options and risks of replantation were explained to parents. The consent form was read, explained and signed by the patient's parents. The surfaces of the root and socket were rinsed with saline solution and any remaining debris was carefully removed. The tooth was kept in %2 sodium fluoride (NeutraRinse, Germiphene, Canada) solution for 20-min. Cold plasma (PiezoBrush PZ3, Regensburg, Germany) was applied to the avulsed tooth surface to provide antimicrobial effects at 8 kilovolts for a duration of 10-min (Figure 4).

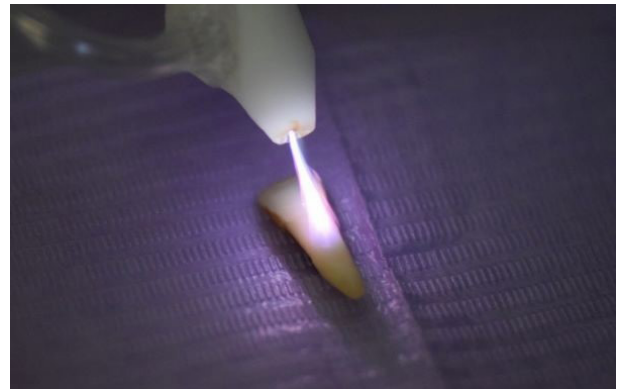


Figure 4. Cold plasma applied to the avulsed tooth surface.

Cold atmospheric plasma was applied using a plasma jet device. The plasma tip was positioned approximately 5 mm from the root surface, and the application was performed circumferentially over the entire root surface. The selected application parameters were based on previously published in vitro studies demonstrating effective antimicrobial activity without causing damage to dental hard tissues. Left maxillary central incisor was slowly placed in the socket, and splinting was achieved using a 0.7 mm twist flexible arch wire for two weeks (Figure 5).



Figure 5. Splinting was achieved using a 0.7 mm twist flexible arch wire from the right canine to the left canine.

The access cavity was opened, and the root canal was instrumented. Subsequently canal was filled with temporary calcium hydroxide (Merck, Darmstadt, Germany) medicament. The access cavity was sealed with a glass ionomer cement (Kavitan Cem, Markova, Czech Republic).

Right maxillary central incisor had a complicated crown fracture that exposed the pulp (Figure 6). The exposed area was cleaned with sterile saline solution. The pulp was amputated to a depth of 2 mm using a stainless-steel round bur under water cooling. Bleeding was controlled by impregnating cotton pellets with 2.5% NaOCl (Cerkamed, Wojciech Pawłowski, Poland) for 5-min. MTA (Angelus, Kerr, USA) was then applied over the exposed pulp tissue, and the broken piece was bonded using flowable composite resin. (Gradia Direct, GC Company, Belgium)



Figure 6. The maxillary right central incisor has a complicated crown fracture exposing the pulp.

Oral hygiene recommendations were also provided. Chlorhexidine, including a mouth rinse and prophylactic antibiotics, was prescribed. The parents were also informed and directed towards the tetanus vaccine. The patient was recalled after two weeks, and the splinting wire was removed at this appointment. The reimplanted tooth was endodontically treated, and root canal treatment was completed. The patient was clinically and radiographically controlled at three months, one year, and three years (Figure 7, 8). During follow-up visits, clinical evaluation included assessment of tooth mobility, percussion sound, presence of pain or discomfort, gingival inflammation, and periodontal probing depths. Radiographic evaluation focused on the detection of

periapical radiolucencies, external inflammatory root resorption, replacement resorption, and changes in the periodontal ligament space. Ankylosis was assessed clinically by percussion testing and evaluation of physiological mobility, and radiographically by the presence or absence of the periodontal ligament space. Root resorption was evaluated using serial periapical radiographs obtained during the follow-up period.



Figure 7. Three-year follow-up.



Figure 8. Three-year follow-up periapical radiograph.

Discussion

Following dental trauma, several treatment options are available, including replantation, pulpotomy, and root canal treatment, depending on the type and severity of injury. Vital pulp treatment is preferred because it maintains the vitality of the tooth, allows continued tooth development, is less invasive and cheaper, and avoids complications related to root canal treatment.⁷

In this case report, vital pulp therapy was performed 1

day after trauma. However, necrosis of the pulp tissue was not observed 2 years after trauma. Furthermore, partial pulpotomy, which requires the removal of only 2 mm thickness pulp tissue, is less invasive than total coronal pulpotomy. Therefore, partial pulpotomy was preferred for the treatment of fractured teeth in the present study.

Tricalcium silicate materials, such as MTA, are contemporary materials that are used for several purposes, including vital pulp therapy. Ford et al. found that MTA is superior to conventional calcium hydroxide in terms of dentin bridge formation.⁸ Thus, the continued vitality of the fractured teeth in the present study may be related to the use of MTA over the exposed pulp.

Immediate replantation of the avulsed tooth is accepted as a general rule because if the extra-oral time exceeds 60-min, periodontal ligament cells (PDLc) are unable to survive.⁹ According to previous studies, PDL cells become necrotic following delayed replantation, which inversely affects prognosis.^{9,10} However, delayed replantation of avulsed teeth, which carries the risk of ankylosis, may be required.¹¹ In such cases, delayed replantation can be performed considering benefits such as maintaining aesthetic appearance, gaining occlusal function, and preventing psychological trauma and bone resorption. Furthermore, loss or extraction of teeth in a growing alveolar process will result in resorption of the crest and disruption of the development in that region, which will decrease the change in future implant placement.

In delayed replantation of avulsed teeth, external inflammatory resorption and replacement resorption are frequently reported complications. Inflammatory resorption is mainly triggered by bacterial toxins penetrating dentinal tubules, whereas replacement resorption occurs as a result of extensive damage to periodontal ligament cells, leading to ankylosis and gradual substitution of root structure by bone.⁹

In the present case, no clinical or radiographic signs of inflammatory or replacement resorption were detected during the three-year follow-up period. This favorable outcome may be attributed to storage of the avulsed tooth in milk, fluoride treatment of the root surface, timely endodontic intervention, and effective control of microbial contamination.⁹

Another important factor affecting prognosis is the transport media of the avulsed tooth. Milk is a suitable storage medium owing to its osmolality and pH value, which allow the protection of PDL cells for up to 8 h. The present case report shows that prolonged extra-oral time in milk may also be possible. Moreover, maintaining teeth in a 2.4% acidulated sodium fluoride solution for 20-min before delayed replantation is recommended, which makes the root surface resistant to resorption.¹² During the treatment phase, the avulsed tooth was kept in fluoride. This may have aided physiological healing rather than ankylosis.

According to various studies, the use of cold plasma has highly significant results in terms of antimicrobial effects. In addition to its antimicrobial effects, cold atmospheric plasma has been shown to improve surface bioactivation and reduce bacterial contamination on dental tissues.¹³ These properties may be particularly beneficial in delayed tooth replantation, where prolonged extra-oral time increases the risk of microbial colonization and inflammatory complications. In the present case, the application of cold atmospheric plasma prior to replantation may have contributed to the favorable clinical outcome observed during the three-year follow-up period by supporting periodontal healing and limiting resorptive processes.¹⁴ Cold atmospheric plasma was preferred in this case due to its reported antimicrobial efficacy, surface bioactivation properties, and non-thermal nature, which allows application without causing structural damage to dental tissues.

Li et al.¹³ demonstrated that plasma exhibited a more significant antibacterial effect than calcium hydroxide. Moreover, Argon Oxygen Plasma treatment for 12-min completely eliminated the *E. faecalis* biofilm from the canal. In this case, cold plasma was applied before re-implanting the avulsed tooth that had been in the extraoral environment for a long time to eliminate possible microbial effects. Cold atmospheric plasma may have contributed in the absence of any symptoms and resorption of the tooth in the follow-up appointments of the patient. This finding suggests that cold atmospheric plasma may represent a promising adjunct for late replantation.

A semi-rigid splint for two weeks is necessary for

avulsion injuries because rigid splints may accelerate root resorption. Furthermore, temporary calcium hydroxide dressing for one week after replantation is also recommended. Long-term clinical investigations and case reports have consistently shown that the use of calcium hydroxide in the treatment of avulsed teeth achieves an exceptionally high success rate.¹⁵

In general, a follow-up period of two years has been accepted as sufficient for a significant reduction in replacement. Although the patient was recalled at 3 months, 6 months, 1 year, and 2 years after the trauma, further clinical and radiographic recall examinations will continue because the risk of root resorption is still present. Cone-beam computed tomography was not performed because no clinical or radiographic findings indicated complications requiring three-dimensional imaging. Additionally, unnecessary radiation exposure was avoided in this pediatric patient in accordance with the ALARA principle.

Conclusion

In this case report, the cold plasma technique, a novel treatment for delayed replantation, was used. This method aims to minimize complications that may arise from delayed replantation. No ankylosis or resorption was observed after three years of follow-up.

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