New emphasis in the treatment of dental trauma: avulsion and luxation

Lin S, Zuckerman O, Fuss Z, Ashkenazi M. New emphasis in the treatment of dental trauma: avulsion and luxation.

Abstract – There are several protocols for the successful management of dental trauma emergencies. However, these existing protocols are inconsistent regarding several issues. As the Israeli dental community and patients have specific characteristics, a modified and adaptable protocol was required. This new protocol contains simple and straightforward clinical guidelines, arranged in table format, according to the nature of the trauma. The present study shows the protocol for luxation and avulsion injuries, with new recommendations for the treatment of luxated closed-apex teeth, the preferred at-site treatment and storage medium for avulsed teeth, and the conditioning of the root surface in these cases. To emphasize and explain the modification of this new protocol, research-based information has been incorporated.

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An obstacle that stands before the general practitioner is to analyze the abundance of data from the professional literature and to apply it in clinical practice. In the area of dental trauma, this is especially important. To simplify the information obtained in this field, several protocols are available that include treatment instructions according to the type of injury. Today, there are three recognized protocols, published by the American Association of Endodontists, the International Association of Dental Traumatology, and the Royal College of Surgeons of England (1–3). However, these protocols have noted differences regarding the recommended method of treatment.

In Israel, dentistry and its patient population have several unique characteristics that require preparation of a specific protocol. The small number of specialists in the field of traumatic dentistry and the lack of even distribution of these specialists throughout the country create a situation in which treatment in dental injury rests mainly on general practitioners (4). Furthermore, a low compliance for recall and long treatment periods has another effect on the treatment consideration. The Israeli protocol is based on the existing protocols and a multidiscipline collection of knowledge, adjusted to Israel's special features, which can be adapted to other countries.

Patient examination

The primary examination and follow-up are important for successful treatment. This includes a written notation of the patient's chief complaint, a neurological examination, an extra-oral examination which includes soft tissues (including lips to rule out the penetration of foreign objects), the temporomandibular joint (TMJ) and the jaws (including occlusal line). As dental injury may be accompanied by head–neck injury, several basic parameters should be assessed to obtain the correct diagnosis. Before pain relievers or sedation are administered, neurological damage should be verified by evaluating whether there is a change in consciousness; confusion, nausea, vomiting; difficulty in breathing, suspicion of foreign object inhalation; eyesight and eye movement; neck pain and limitation of movement; and accompanying injuries to the soft tissues and/or jaws. A patient with any of these signs or symptoms should be referred for immediate medical attention.

Signs of external injury, such as wounds, should be checked during the extra-oral examination to

rule out the presence of fractures by palpation of the bones, including the zygomatic arch, and the entire mandibular jaw, including the ramus and border. Any sensitivity could indicate a fracture. The TMJ should be examined by palpation while the mouth is in an opened and closed position. A unilateral fracture should be suspected when there is a shift of the mandible during mouth opening.

During intra-oral examination, the soft tissues in all areas of the mouth should be examined for the presence of wounds on the lips, tongue, palate, and floor of mouth. A radiograph of the area should be taken for an open wound to rule out penetration of a foreign object. All teeth and supporting tissues should be re-examined.

The current Israeli protocol focuses on luxation and avulsion, presented in table form, for easy use. Table 1 presents treatment guidelines for luxated permanent teeth and Table 2 presents treatment indications for avulsed teeth.

Discussion

Luxation

All protocols recommend follow-up in cases of luxation (lateral and extrusive), and performance of root canal therapy only where there is a lack of response to vitality examination and/or radiographic evidence of periapical involvement. This approach is based on the possibility of revascularization after injury (5), and relates to teeth with open and closed apices. In the current protocol, follow-up is recommended only for teeth with open apices. Root canal therapy is recommended for all teeth with closed apices, except in cases of subluxation and concussion.

This difference in approach is because of the low probability of revascularization in teeth with closed apices (6), and the prevention of serious consequences associated with an infected necrotic pulp. The low probability of revascularization is attributed to the character of blood supply to the tooth pulp. Nourishment of the tooth pulp is attained through a central blood vessel or arteriole, 50 μm in diameter, which penetrates through the apical foramen. This arteriole is enveloped in several layers of smooth muscle cells that protect it from tearing (7, 8). However, any tooth movement greater than twice the diameter of the vessel can cause its rupture (9, 10). This could result in pulp necrosis in opened and closed apices due to the lack of collateral blood vessels and could provide an alternative to the primary blood supply, if they exist (11).

In the revascularization process, there is penetration of connective tissue and blood vessels from the periapical tissues into the root canal space (12, 13). This process is possible only in a tooth with an open apex, because of the wide apical foramen. In a tooth with a closed apex, where the apical foramen is smaller than 1 mm, this process is impossible (6). Therefore, root canal therapy is recommended for these teeth at the second appointment (removing splint), before the necrotic pulp becomes infected. This approach is preferable because of the difference between success rates of root canal therapy in a tooth with a closed apex in which a periapical lesion has not yet developed (96%) vs the lower rate of success (86%) in a tooth with a periapical lesion (14).

Avulsion

According to the International Health Organization, avulsion is the complete displacement of the tooth from the alveolar socket. This injury involves the supporting tissues (cementum, PDL, bone) and dental pulp (15, 16), with a 16% incidence rate of all dental injuries to permanent teeth (17, 18). The primary goal in treating this type of injury is to preserve and treat the supporting tissues of the tooth. The most important factor from the moment the tooth is avulsed from the alveolar socket is time. As the time between avulsion to reimplantation increases, the danger of replacement resorption increases, and revascularization decreases (in teeth with an open apex) (16, 19, 20). Therefore, the preferred treatment is tooth reimplantation into the alveolar socket at the site of injury. Long-term success depends on the treatment given at the site of the injury (reimplantation/storage medium) and treatment of the root-surface area administered immediately upon arrival at the dental clinic.

Storage medium (preservation of PDL cells)

In the event where tooth reimplantation at the site of injury is impossible, the tooth should be placed in a storage medium to diminish injury to the cells. This lengthens the time lapse until tooth reimplantation can be performed. The PDL remaining on the root after injury is dependent on a supply of vital metabolites. When these metabolites are withheld, cell destruction begins. To preserve optimal cell metabolism, the supply should be renewed within 60 min from the time of injury (19). These cells, if they survive, will catalyze the reproduction of new cells, which can differentiate and reinstate the supporting tissues.

There are several types of storage mediums: milk, Viaspan, Hanks balanced salt solution (HBSS), saliva, and saline. According to the American Association of Endodontists, the preferred storage medium is HBSS, because of its ability to preserve

Table 1. Treatment guidelines for luxated permanent teeth

Clinical status	Concussion	Subluxation	Lateral luxation	Intrusion	Extrusion
Clinical findings	Tooth sensitive to palpation and percussion, normal mobility and no change in tooth position	Tooth sensitive to palpation and percussion, increased mobility with no change in tooth position. Gingival damage and bleeding from the alveolar socket may occur	Tooth laterally repositioned	Tooth intruded into the alveolar ridge. No mobility, metallic sound upon percussion	Tooth sensitive to palpation and percussion, and repositioned coronally. Alveolar bleeding and gingival damage may be possible
X-ray findings	No radiolucencies	No radiolucencies	Widened PDL	Absence of PDL	Widened PDL
Clinical treatment	No treatment indicated	Non-rigid splint (only in severe cases or occlusion trauma) to adjacent teeth (two teeth on each side) using composite and dental floss or thin passive orthodontic wire for 10–14 days	Session I: emergency care. Anesthetize area and return tooth to original position. X-ray to determine correct position of tooth Non-rigid splint to adjacent teeth (two teeth on each side) using composite and dental floss or thin passive orthodontic wire for 10–14 days Selective grinding to free tooth from occlusal forces	Closed apex: immediately return tooth to original position by orthodontic forced eruption. Surgery may be indicated for crown exposure Open apex: spontaneous eruption may occur. If tooth does not erupt naturally, employ orthodontic eruption	Session I: emergency care: anesthetize area and return tooth to original position. X-ray to determine correct position of tooth
Preliminary examination for diagnosis: patient history, clinical examination, vitality tests, X-rays			Suture of gingival lacerations, especially in the cervical area.	After tooth reaches occlusion:	Non-rigid splint to adjacent teeth (two teeth on each side) using composite and dental floss or thin passive orthodontic wire for 10–14 days Selective grinding to free tooth from occlusal forces
Periodical follow-up: after injury 3 weeks, 3, 6, and 12 months; then yearly		Suture of gingival lacerations, especially in the cervical area	Session II: upon splint removal. Closed apex: root canal treatment. Canal may be filled after dressing with $CaOH_2$ for 1 week	Closed apex: root canal treatment. Canal may be filled after dressing with $CaOH_2$ for 1 week Open apex: follow-up. Root canal treatment indicated when pulpal necrosis has been diagnosed. $CaOH_2$ recommended for 12–24 months or until apexification is completed before filling with gutta percha and cement	Suture of gingival lacerations, especially in the cervical area
Follow-up includes: patient's history, clinical examination, vitality testing, X-rays as needed			Open apex: follow-up. Root canal treatment indicated when pulpal necrosis has been diagnosed. $CaOH_2$ recommended for 12–18 months, before filling with gutta percha and cement. Follow-up	Note: patient should be advised as to the high risk of replacement resorption	Session II: upon splint removal: closed apex: root canal treatment. The canal may be filled after dressing with $CaOH_2$ for 1 week Open apex: follow-up. Root canal treatment indicated when pulpal necrosis has been diagnosed. $CaOH_2$ recommended for 12–24 months, before filling with gutta percha and cement. Follow-up

Table 1. Continued

Clinical status	Concussion	Subluxation	Lateral luxation	Intrusion	Extrusion
Patient instructions			Soft diet for 2 weeks Brush teeth after every meal with a soft-bristle brush Rinse mouth with chlorhexidine (0.2%) twice daily for 1 week Regular follow-up as indicated according to type of trauma. Systemic antibiotics: amoxicillin: loading dose of 1000 mg, followed by 3 × 500 mg day^{-1} for 7 days. In case of penicillin allergy: clindamicin 150 mg, four times a day for 7 days Clindamycin (Dalacin) child: 10 mg kg^{-1} day^{-1}, divided in 3–4 equal doses		

the vitality of PDL cells for a longer duration. The medium is of ideal osmolarity and pH needed to preserve cell vitality (21–23). Hiltz & Trope (22) have shown that HBSS preserved the vitality of fibroblast cells for 72 h. As this medium is not commonly found in Israel, it can be assumed that it will not be on hand in time of need.

Viaspan is a storage medium used in transport of organs to the site of transplantation. Its main disadvantage is its short shelf-life of only a few months. This fact, together with its high price, makes its use rare.

Saliva is a medium that can preserve PDL cell vitality up to 2 h (24, 25). However, the fear of cross-contamination of bacterial or viral infection (e.g. viral hepatitis) from the carrier, whose saliva is used to store the tooth, to the tooth recipient, is the main reason not to use it. Even if the tooth is carried in the recipient's mouth (26), there is still the possibility of self-contamination of the pulp and root surface, which can lead to reimplantation failure (27, 28).

Saline as a storage medium can preserve vitality for only 2 h. It is not usually available in public places, and is less effective than milk. As milk is the most common and readily available medium, and is efficient, due to its physiological osmolarity, neutral pH, and presence of nutrients (21, 29, 30), it is the medium of choice. Milk allows a possible storage time of up to 3 h (24, 25).

Conditioning (preparation of the root surface)

There are two types of preparation of the root surface possible before tooth reimplantation: coating the tooth with tetracycline, or soaking the tooth in a fluoride solution. The decision is based on the amount of time lapsed from the time of injury and on the type of medium in which the tooth was stored until reimplantation.

A tooth that remains out of the mouth in a dry condition for less than 60 min, or stored in one of the recommended mediums within the advised time frame, the proper conditioning is to coat the root surface with tetracycline and reimplant. In the event that 60 min have passed in dry conditions, or the tooth remained in a recommended medium longer than the advised time period, then the tooth should be soaked in a fluoride solution before reimplantation.

Conditioning using tetracycline

When extracted monkey teeth were treated with topical doxycycline (1 mg/10 ml for 5 min) before reimplantation, the use of antibiotics raised the frequency of revascularization significantly to 41% vs 18% in the control group. Furthermore, this

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Table 2. Treatment indications for avulsed teeth

Emergency on-site treatment	Holding the tooth by the crown, rinse gently with chlorhexidine, saline, water or milk. Gently clean injured area with water, saline or chlorhexidine and replant tooth in its position. Refer patient to dental clinic immediately		
First session (emergency treatment): dental care according to clinical status (A, B, C)	A Tooth replanted in the socket on-site. Patient has reported for continuation of treatment.	B Tooth stored in special medium, such as saline solution or saliva (up to 2 h after injury) or milk (up to 3 h after injury) or dry (less than 60 min)	C Tooth stored in dry surroundings for longer than 60 min or longer than recommended time in other media (in patients under 18; older patients *should be considered for implant therapy)
	Proceed to treatment according for each clinical status.	Remove tooth from medium avoiding contact with the root. Gently apply antibiotic solution to the root surface (place root in doxycycline solution (1 mg 10 ml^{-1} saline) or dip in minocycline (Arestin^{TM}). Anesthetize and remove blood clot from socket with saline or chlorhexidine. A diagnosed alveolar wall fracture should be reduced. Reimplant tooth applying light pressure	Remove cementum with gentle brushing and place tooth in a topical fluoride (APF 1.23% F^{-}) solution for 15 min. Remove blood clot from socket with saline or chlorhexidine. A diagnosed alveolar wall fracture should be reduced. Root canal treatment should be performed extra-orally
Dental treatment for each clinical status (A, B, C)	X-ray to ensure correct tooth position within the socket Non-rigid splint to adjacent teeth (two teeth on each side) using composite and dental floss or thin passive orthodontic wire for 10–14 days Suture of gingival lacerations, especially in cervical areas Selective grinding to free tooth from occlusal forces		
Patient instructions	Soft diet for 2 weeks Brush teeth after every meal with a soft-bristle brush Rinse mouth with chlorhexidine (0.2%) twice daily for a week Systemic antibiotics: amoxicillin: loading dose of 1000 mg, followed by 3 × 500 mg day^{-1} for 7 days. In case of penicillin allergy: clindamicin 150 mg, four times a day for 7 days Child: 10 mg kg^{-1} day^{-1}, divided in 3–4 equal doses		
Second session, 10-14 days later (A, B, C)	In cases A, B: root canal treatment upon splint removal Open apex: treatment may be completed after dressing with $CaOH_2$ for 1 week Closed apex: splint removal and follow-up. If pulp necrosis is diagnosed, $CaOH_2$ is indicated for 12–18 months (for apexification) prior to filling with gutta percha and cement In case C: splint removal only		
Patient instructions	Follow-up: after 3, 6, and 12 months; then yearly.		

*After bone growth.

treatment lowered the frequency of inflammatory root resorption to 30% vs 66% in the control group and the frequency of ankylosis to 48% vs 68% in the control group (27). Ritter et al. (31) studied the effect of the antibiotic minocycline (Arestin^{TM}). Coating the root surface of teeth with open apices in dogs and reimplanting after 5 min outside the mouth, led to revascularization in 90% of the cases vs 73% with doxycycline, and only 33% with saline.

Factors that mostly effect pulp revascularization are the size of the apical foramen and the extra-oral dry time of the tooth (6, 20, 32). Andreasen et al. (33) found that revascularization can occur in a tooth with an open apex. Therefore, the goal is to reimplant the tooth with follow-up examinations, which are necessary to prevent inflammatory root resorption of the tooth in the event of necrotic pulp infection. The patient should be followed-up every 3 or 4 weeks to ensure pulp vitality. Recently, it was found that the occlusal tooth edge, near the pulp horns, is the best location to examine vitality of young permanent teeth (34). Radiographs should also be taken to verify signs of developing periapical lesions and/or root resorption (apical or lateral resorption, and signs of bone resorption). The existence of clinical signs and symptoms, such as pain to percussion or swelling, should be ruled out. Any change in the situation of the tooth signifying damage to the pulp or attachment system necessitates an immediate procedure of apexification.

Revascularization of a tooth with an open apex is always better than the therapeutic option of apexification. When revascularization of the pulp occurs, the tissue in the canal space prevents penetration of infection, thus normal root development is continued. An important advantage is the lowered risk of root fracture caused by thinned tooth walls. It was found that in 30% of the cases in which a tooth was treated successfully by apexification the tooth became fractured during or after treatment (18, 35).

Bacterial presence in the canal space is a main factor that may prevent revascularization. Bacteria create an inflammatory environment which does

not allow healing and revival of tissue in the canal. Furthermore, bacteria on the root surface could heighten the inflammatory response and further damage to the periodontium resulting in replacement or inflammatory root resorption and tooth loss (27, 31).

Tetracycline is an antibiotic with a wide antibacterial range, including anaerobic and facultative bacteria. Its mechanism of action involves the prevention of protein synthesis in the bacterial cell (36). In addition to its antibacterial action, tetracycline can minimize the damage of the inflammatory process by delaying the action of the enzyme matrix metalloproteinase (MMP), a collagenase that breaks down collagen in connective tissue (37). Tetracycline encourages the action of fibroblasts and the healing of connective tissue, which contributes to the recovery of the PDL after injury (38). Its antibacterial effect favors the revascularization, due to the removal of bacteria presence in the root canal space. These bacteria are, as previously mentioned, the primary factor in preventing the redevelopment of tissues into the root canal space and responsible for the process of inflammatory root resorption.

Revascularization does not occur in a tooth with a closed apex. Nevertheless, conditioning the tooth by applying a topical antibiotic ointment can contribute to minimal resorption as a result of injury. Frequency of replacement resorption and of inflammatory root resorption was significantly lowered compared to a control group (27).

Conditioning using fluoride solution

When a tooth remains out of the mouth for over 60 min in dry conditions, all of the periodontal cells on the surface die (12, 39, 40). In this situation, replacement resorption is almost unpreventable. Therefore, the goal is to make the root more resistant to resorption by slowing the rate of the process by removing with gentle brushing the necrotic tissue from the root surface external surface, and soaking the root in topical fluoride (APF 1.23% F^-) for 15 min. This process makes the root more resistant to resorption.

As there is no need to immediately reimplant the tooth in the alveolar socket, it is advisable to perform root canal therapy outside the mouth. The tooth should be held with a gauze pad dipped in chlorhexidine or saline. Root canal therapy itself is performed in the conventional manner. Aseptic methods should be used to prevent bacterial infection. This process is performed only in roots with open apices and eliminates the need for the entire process of apexification.

Summary

The goal of this protocol is to provide clear instructions to simplify the process of decision making and treatment of luxation and avulsion.

1. In teeth with a closed apex, root canal therapy should be carried out in teeth with injuries of luxation and avulsion (except for injuries of subluxation and concussion) at the second appointment.
2. Tooth roots that have been avulsed should be conditioned.
3. When possible, the tooth should be re-implanted at the site of the accident.
4. The preferred storage medium is milk for avulsed teeth.
5. In teeth that have not completely developed, the preferred treatment is to allow the root to continue to develop.

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