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History of the Dental Trauma Guide

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Abstract – The history of the Dental Trauma Guide dates back to 1965, where guidelines were developed for trauma records and treatment of various trauma entities at the Department of Oral and Maxillofacial Surgery at the University Hospital in Copenhagen. In 1972, a unique possibility came up at the Serum Institute in Copenhagen to test various dental trauma procedures in monkeys, which served as kidney donors in the polio vaccine production. Over the years, 40 000 dental trauma patients were treated at the Trauma Centre according to established guidelines, and 4000 of these have been enrolled in long-term follow-up of various trauma entities. This has resulted in 79 clinical studies, and 64 studies in monkeys have examined the effect of various treatment procedures and the aetiology of most healing complications.

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In 1965, an important decision was taken at the Trauma Centre, Department of Oral and Maxillofacial Surgery at the University Hospital in Copenhagen: a periodic follow-up record would be made of all patients treated for traumatic dental and maxillofacial injuries. At that time, the department had the sole responsibility for treatment of traumatic dental injuries in the eastern part of Denmark with a population of close to two million inhabitants.

The treatment principles followed at the time were based on the 1960 textbook *The Classification and Treatment of Traumatic Dental Injuries* by Ellis (1), which relied on to a large extent on case reports and expert opinions that were available. Because of the lack of good scientific material in the field of dental traumatology level, evidence provided the only basis for treatment decisions.

It soon became apparent from follow-up control visits of trauma patients that treatment regimens based on these sources of information often led to serious healing complications. These complications were highlighted in a series of *retrospective* studies covering *avulsions* with subsequent *replantation* (2, 3), *root fractures* (4, 5), *alveolar fractures* (6), jaw *fractures* (7) and *luxations injuries* (8). The healing complications recognized in these clinical and radiographic follow-up examinations were *pulp necrosis, pulp canal obliteration* (PCO)*, progressive root resorption* and *loss of supporting bone*.

An attempt to establish a cause–effect relationship between type and extent of trauma, treatment modality and subsequent development of complications was seriously hampered by the incomplete data present in the patient records, as well as insufficient initial radiographic documentation of the extent of injury. The first step to rectify this situation was to establish a classification system for dental trauma injuries covering all the possible injuries to the hard dental tissues, the periodontal tissues and the alveolar bone. As a model, the WHO classification system was selected and a few missing trauma entities were added (concussion, subluxation and lateral luxation) to cover all the biologically distinguishable injury scenarios (9). This classification system has since gained a wide acceptance and has been used in all our subsequent trauma studies.

To improve the quality of the patients' trauma records at the University Hospital and increase their value for research, a standardized trauma form was developed and implemented in 1966. This standardized patient record was quite comprehensive and contained all necessary details about the type and the extent of injury, patient characteristics (e.g. stage of root development, age and sex) as well as information about the treatment provided. Altogether 65 pieces of information about the trauma were collected for each patient. In 1969, a *standardized radiographic examination* procedure was developed using three radiographic projections of each traumatized tooth, and in 1971, *photographic documentation* was added to include a facial photograph of the oral region to register associated lip injuries, as well as a frontal and an axial photograph of the injured teeth (Fig. 1). In case of primary teeth similar documentation was made including for some patients a control at 10 years of age in order to register developmental disturbances affecting permanent successors (Fig. 2). To complement the initial records, the follow-up procedures were carried out at predetermined intervals, chosen based on experience as representing the optimum times for recognizing healing complications. Whenever treatment failed and teeth were removed, they were examined at the Department of Oral Pathology at the Dental School, which had strong ties to the University Hospital (the senior author having a dual appointment at both institutions). In the 1970s and 1980s, sufficient standardized data had been accumulated to enable us to make *prospective clinical trauma studies,* and altogether 79 publications covering all trauma entities affecting the primary as well as the permanent dentition have since been completed (2–70).

In the early 1970s, a unique opportunity for doing *experimental dental traumatology* occurred, when the senior author was able to do research on monkeys used at the Danish Serum Institute; these animals were used as kidney donors for polio vaccine production. The experiments conducted on these monkeys resulted in 64 experimental dental trauma studies including some *in vitro* studies (71–135).

In a board meeting in 2005, I got an IADT mandate to initiate the development of the Dental Trauma Guide. This cooperation project between the IADT and the Copenhagen University Hospital was intended to create a visualization of the IADT Guidelines and to facilitate prognosis estimation of individual trauma entities based on the extensive trauma database at the Copenhagen University Hospital.

In the following section, the volume of clinical and experimental information available for each trauma type will be described. This information is essential as it shapes the approach used by the Dental Trauma Guide for each individual trauma entity in relation to *diagnosis* and *treatment selection* and *prognosis estimation*.

Luxation injuries

Concussion, subluxation, extrusive, lateral and intrusive luxations involving the permanent dentition were analysed in a series of prospective studies (16, 17, 20–22, 66–70), and healing complications such as pulp necrosis, PCO (22), external and internal root resorption (29),

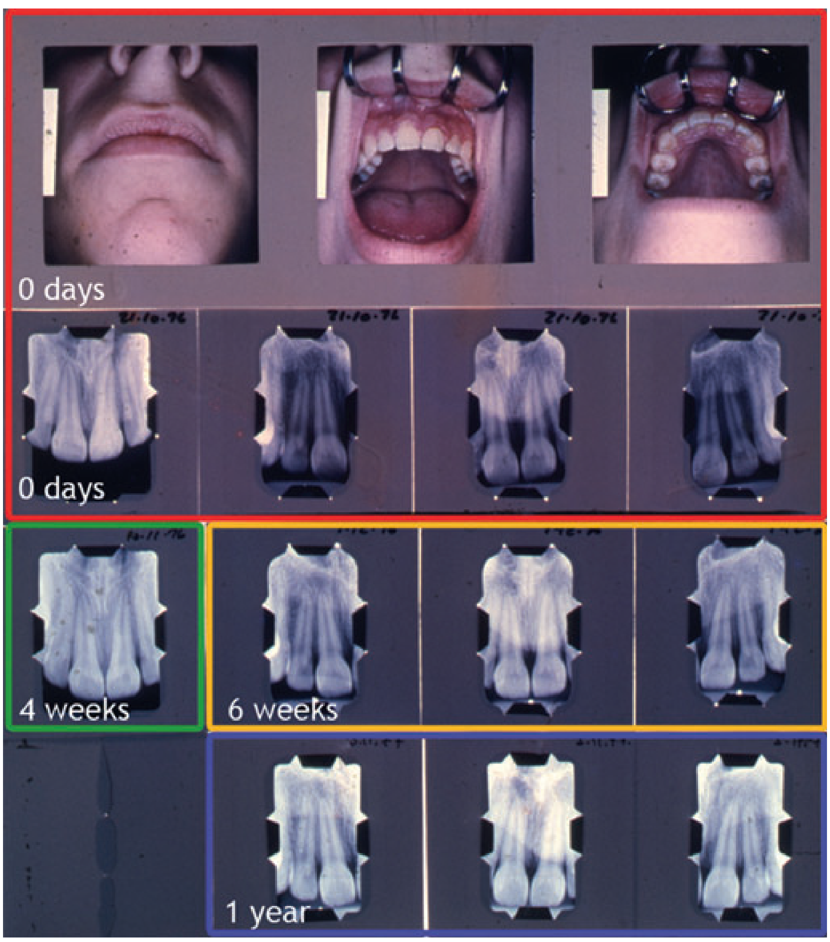

Fig. 1. Standardised photographic and radiographic examination of traumatised permanent maxillary incisors. The examination was terminated after 1 year in this patient.

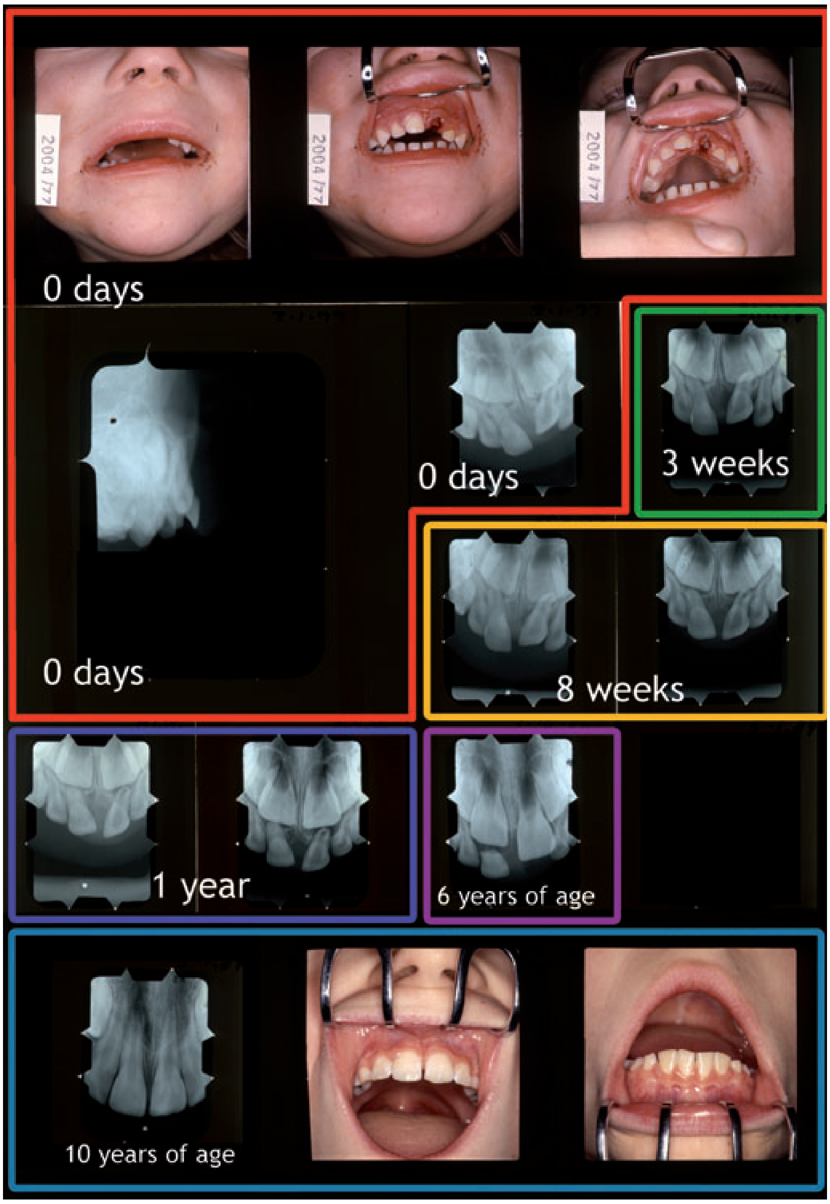

Fig. 2. Standardised photographic and radiographic examination of primary maxillary incisors. The control of the primary incisors included an examination at the age of 6 and 10 years of age. At the latter control sequels to the permanent dentitian was examined.

transient and permanent marginal bone breakdown (16, 17) and transient apical bone breakdown were analysed in detail (21, 26, 46). The aetiology and pathogenesis of *pulp necrosis* was examined especially in relation to luxation type and stage of root development (17). The aetiology and pathology of PCO was another pulpal-healing complication studied, and a strong relation was found between the occurrence of PCO and the initial displacement (severance of the apical blood supply) and the stage of root development (22). The long-term effect of PCO (i.e. up to 20 years) was analysed in a joint study by Robertson et al. (37) from Gothenburg Dental School, Sweden, and a slightly increased yearly risk of subsequent pulp necrosis was established for teeth with PCO.

Periodontal healing complications were also analysed, and a strong relation was found between root resorption events and the type of luxation (54, 55, 66–70). Furthermore, for intrusions, a relationship was found between the choice of initial treatment and frequency of subsequent root resorption (51–53).

Avulsion injuries with subsequent replantation

The first clinical *retrospective* study of 110 replanted teeth was published in 1965 and showed a significant relationship between the length of the extraoral dry time and subsequent healing complications, such as pulp necrosis and progressive root resorption (3). A study of 22 extracted and histologically examined human teeth showed that root resorption events could be divided into surface resorption, inflammatory resorption and replacement resorption (3). A terminology later changed to *repair-related resorption*, *infection-related inflammatory resorption* and *ankylosis-related resorption*.

A histological study demonstrated that infection-related resorption had its origin in the presence of bacteria located in the root canal and dentinal tubules (3), and a clinical study showed that root canal treatment could prevent and arrest infection-related resorption in about 32% of the cases (2). A few years later, it was discovered that calcium hydroxide was effective in preventing and arresting infection-related resorption in 90% of the cases (12, 56).

In the early 1970s, a series of experiments in monkeys were initiated to study the pathogenesis of the root resorption types subsequent to replantation (78–89) and to evaluate the effect of various treatment procedures on the outcome of replantation of permanent teeth. Among the procedures and factors tested were the effect of removing the *coagulum* before replantation (83), the *size* of the detrimental effect caused by *dry* and *wet extra oral time*, the effectiveness of various *storage media* and their *temperatures* (86, 99, 106, 130), *cleansing procedures* of the root surface before replantation (94), *exactness of repositioning* (92, 103), *splinting methods* (rigid or flexible) and *length of time of splinting* (71, 100), *occlusal overload* during healing (91) and *endodontic treatment* before replantation (93, 96, 110, 111, 115, 119). At that time, a research collaboration concerning design of the experimental procedures and histological healing classification was arranged between colleagues at the Dental School in Stockholm (Drs L. Hammarström, L. Andersson, S. Lindskog, L. Blömlof) and Dr M. Cvek and Dr B. Malmgren and Dr O. Malmgren at the Eastman Dental Institute in Stockholm (107, 108, 117, 118). Similarly, a series of experiments concerning the effects of *antibiotics* and *masticatory stimulation* upon healing of pulp and periodontal ligament after replantation were also carried out by these authors (132, 135). Since then an important new treatment procedure decoronation had been developed for ankylosed teeth by Malmgren et al. (57).

In 1994, the first *prospective* study of 400 replanted human teeth with follow-up periods of up to 20 years after replantation was published. Owing to the detailed information about the significant relation between extra-alveolar storage condition and later occurrence of pulp and periodontal healing complications, a detailed survival analysis could be established for replanted teeth with a given set of extra-alveolar conditions (33–36).

Crown fractures with and without pulp exposure

We are currently working on a prospective study encompassing 1137 permanent teeth including all four types of crown fractures (infractions, enamel, enamel–dentin and enamel–dentin–pulp fractures) as well as combinations with the above-mentioned five luxation types (67–70). For all fractures types and their combination, healing rates are documented in relation to pulpal and periodontal ligament healing.

In 1985, a new bonding system (Gluma®, Bayer AG, Leverkusen, Germany) was developed by Dr Asmussen and Dr Munksgaard at the Dental School in Copenhagen in cooperation with the ESPE® company (3M Deutschland GmbH, Neuss, Germany), and it was decided to use the system to rebond the retrieved crown fragments (27, 28). In 1991, a Scandinavian multicentre study (Gothenburg, Sweden, Oslo, Norway, and Copenhagen, Denmark) showed that the method had some promising long-term results (31), but debondings of glued fragments often occurred because of mastication or a new trauma, both events indicating the necessity of further improvement in the bonding procedure, a fact that indicated a series of new *in vitro* studies (121–126).

Crown-root fractures

The two most common treatment strategies for uncomplicated and complicated crown-root fractures, namely restoration after *gingivectomy* ± *ostectomy* and *orthodontic extrusion* + *gingivectomy*, were analysed in a *prospective* long-term study. With regard to the stability of the restored tooth in the dental arch and the gingival health associated with the restored tooth, significant differences were found between the two methods, in favour of orthodontic extrusion in regard to long-term healing. This study will be published in 2013.

Root fractures

In 1967, the first *retrospective* clinical, radiographic and histological study of 50 root-fractured anterior permanent teeth revealed three main types of healing scenarios, namely healing with interfragment hard tissue, *healing with interfragment periodontal ligament tissue* and finally *non-healing* with *interfragment development of granulation tissue* because of pulp necrosis located in the coronal fragment (4). In 1989, a *prospective* study of 95 root-fractured permanent teeth was completed, and a significant relationship between the healing outcome and the stage of root development and the extent of dislocation was demonstrated (23). Furthermore, because of the periodic identical radiographic examinations, new healing variations could be described such as *internal surface resorption* and *internal tunnelling resorption* (24).

In the early 1970s, a research liaison was established with Dr M. Cvek at the Eastman Dental Institute in Stockholm, and identical recordings of variables in relation to root fractures were arranged. In 2005, a prospective study of 400 root-fractured teeth allowed a detailed analysis of *preinjury factors* (age and root development), *injury factors* (location of fracture and severity of dislocation of the fragment) and finally *treatment factors* (completeness of repositioning, splinting method and time of splinting and administration of antibiotics) (48, 49). Also, the effects of various endodontic treatment procedures were analysed (50). Finally, the long-term fate of root-fractured teeth was published in 2008 (59) and 2012 (59, 63).

Alveolar fractures

In a *retrospective* study, in 1968, the outcome of 29 alveolar fractures involving 71 teeth were analysed, and pulp necrosis and progressive root resorption were found to be very common (6). However, the treatment procedures used at that time have later been shown to be suboptimal. In 2009, a *prospective* study of 84 patients with five alveolar fractures with 200 involved teeth was started up and is now undergoing statistical analyses.

Jaw fractures with tooth involvement

In 1969, a series of 84 mandibular fractures were examined, and a rather high frequency of alveolar bone loss in the fractures was found, a phenomenon primarily related to insufficient repositioning (9).

Primary tooth injuries

In two *retrospective* studies from the early 1970s, the outcome of pulpal and periodontal healing complications was described for luxated primary teeth as well as the implications for the developing successors (10, 11). In a combined clinical and histological study, eight different complications involving the subjacent permanent successors were described. These encompassed *enamel opacities, enamel hypoplasia* with or without a cervically *placed circumferential enamel hypoplasia, crown* or *root dilacerations, root angulation, arrested root formation* and *sequestration of infected tooth germs* (10, 14).

Based on these studies, it was decided to try to develop evidence-based treatment for primary tooth injuries using a monkey model. In several experiments, the effect of treatment procedures such as extraction or awaiting spontaneous eruption was examined (72, 75). Furthermore, the detrimental effects on the permanent successor caused by chronic inflammation in primary teeth because of an untreated pulp necrosis were analysed (77).

Based on these animal experiments, a *prospective* study was started on 270 children with injured primary teeth. All children were followed with annual controls until the age of 6, where all healing complications affecting the injured primary teeth were analysed and related to the type of the luxation injury and stage of root development of the affected tooth at the time of injury (39). At the age of 6, eruption problems were analysed for the succedaneus successors. Finally, the patients were recalled at the age of 10 years, where subsequent developmental changes to the permanent successor could be registered. The material is presently under investigation and will be incorporated in version 2.0 of the *Dental Trauma Guide* to be released in 2013.

Making a unified database for all trauma types

Since systematic registration of all the various trauma types began in 1965, the trauma patients have been examined and followed up using a standardized trauma record. Altogether 40 000 patient records exist, and about 4000 have been included in long-term follow-up studies. These 4000 cases are now part of an extensive database covering the various types of dental trauma injuries. In 2005, the Dental Trauma Guide project was started to use this valuable source of information for prognostic estimation of healing complications after dental trauma based on the IADT Guidelines treatment (136–138). The data make it possible to calculate prognosis estimates for the various injury types and to make comparisons between competing treatment procedures.

The aim and function of the Dental Trauma Guide will be described in a future publication.

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