The Dental Trauma Guide
A population based Internet risk calculator

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Methodological issues in oral health research: Graz, April 11, 2012
Outline

Dental trauma occurs frequently!

- **Eva**
  - Background: dental trauma
  - A 9 year old boy suffers an avulsion
  - The aim and data base of the Internet guide

- **Thomas**
  - The statistical approach behind the risk predictions
  - Results for a prognostic subgroup
  - Discussion and limitations of the project
Dental trauma

- Alveolar bone
- Enamel
- Periodontal ligament
- Pulp (Blood and nerve supply)
- Dentin

Dental trauma Case study Internet guide Statistical methods Results Discussion
Characterization of dental trauma

- Six luxation injury types:
  - Concussion, Subluxation, Extrusion, Lateral luxation, Intrusion, Avulsion

- Eight fracture types:
  - Alveolar Fracture
  - Root fracture
  - Crown-root fracture (compl./uncompl.)
  - Infraction, Enamel fracture,
  - Enamel-dentin fracture,
  - Enamel-dentin-pulp fracture

Different healing scenarios need specific treatment.
The complexity of dental trauma is high!

About 30% of the injured teeth have a combination of a luxation and a fracture injury
Healing complications

**Pulp**
- Pulp canal obliteration
- Pulp necrosis

**Periodontal**
- Repair related resorption
- Infection related resorption
- Ankylosis
- Marginal bone loss
- Tooth loss
The Dental Trauma Guide

**Aim:** To develop a free of charge Internet website

- Diagnosis of traumatic dental injuries
- Guidelines for acute treatment
- Long-term prognosis and appropriate follow-up programs

**Jens Ove Andreasen** and his team:

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1Department of Oral and Maxillo-Facial Surgery, Copenhagen University Hospital, Rigshospitalet, Denmark
9 year old boy falls off his bike
AVULSION

The tooth is completely displaced out of its socket. Clinically the socket is found empty or filled with a coagulum.
**AVULSION - Open Apex**

**Extraoral dry time less than 50 min**

**TREATMENT**
- Clean the tooth with saline
- Local anesthesia usually not necessary
- Evacuate the socket with saline
- Replant tooth with gentle pressure
- Clean the area with water spray, saline, or chlorhexidine
- Suture gingival laceration if present
- Apply resin or wire composite splint for 1-2 weeks
- Administer systemic antibiotics. For children 12 years and younger, Phenoxybenzyl Penicillin (Pen V) dose at an appropriate dose based on patients age and weight
- If tetanus coverage is uncertain, refer to physician for a tetanus booster

**FOLLOW-UP**
- Splint removal and clinical and radiographic control after 2 weeks
- Clinical and radiographic control after 4 weeks, 6-8 weeks, 6 months, 1 year and yearly for 5 years
- Initiate root canal treatment if there is clinical and radiographic evidence of pulp necrosis

**CLEAN OPEN APEX THOROUGHLY**
AVULSION - Open Apex

Extraoral dry time less than 60 min

TREATMENT
- Clean the tooth with saline
- Local anesthesia usually not necessary
- Evacuate the socket with saline
- Replant tooth with gentle pressure
- Clean the area with water spray, saline, or chlorhexidine
- Suture gingival laceration if present
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**N - Treatment Guidelines for Permanent Teeth**

**AVULSION - Open Apex**

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- **Treatment Guidelines for Permanent Teeth**

### AVULSION - Open Apex

**Resin splint**

- **TREATMENT**
  - Clean the tooth with saline
  - Local anesthesia usually not necessary
  - Evacuate the socket with saline
  - Replant tooth with gentle pressure
  - Clean the area with water spray, saline, or chlorhexidine
  - Suture gingival laceration if present
  - **Apply resin or wire composite splint for 1-2 weeks**
  - Administer systemic antibiotics. For children 12 years and younger, Phenoxymethyl Penicillin (Pen V) dose at an appropriate dose based on patients' age and weight
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- **FOLLOW-UP**
  - Splint removal and clinical and radiographic control after 2 weeks
  - Clinical and radiographic control after 4 weeks, 6-8 weeks, and 6 months, 1 year and yearly for 5 years
  - Initiate root canal treatment if there is clinical and radiographic evidence of pulp necrosis
AGUSLION - PROGNOSIS

ROOT DEVELOPMENT

Dry time Wet time physiologic media
- Unknown
- 0-4 min
- 5-60 min
- 5+ min
- Unknown
- 0-4 min
- 5+ min

Due to the limited number of cases with the selected root development stage the chosen immature stage is combined with other immature stages (1-8).

If the tooth has been stored in a unphysiologic medias such as tapwater, chlorhexidine, chloramine, alcohol or other sterilizing solutions no prognosis calculation is possible.

Physiologic medias: Saliva, saline, milk, culture medias

Dear colleague, our data base included 74 teeth with the same diagnosis as yours. These teeth belong to 62 patients. The predicted risks of healing complications are shown in the tables and figures below.
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### Results, one year after the injury

<table>
<thead>
<tr>
<th>Number of diagnosed events</th>
<th>Estimated risk (%)</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth loss</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>Pulp necrosis</td>
<td>52</td>
<td>74.3</td>
</tr>
<tr>
<td>Pulp canal obliteration</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>Ankylosis</td>
<td>28</td>
<td>37.8</td>
</tr>
<tr>
<td>Inflammatory root resorption</td>
<td>27</td>
<td>36.5</td>
</tr>
<tr>
<td>Surface resorption</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>Bone loss</td>
<td>3</td>
<td>4.1</td>
</tr>
</tbody>
</table>

### Results, three years after the injury

<table>
<thead>
<tr>
<th>Number of diagnosed events</th>
<th>Estimated risk (%)</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth loss</td>
<td>16</td>
<td>24.7</td>
</tr>
<tr>
<td>Pulp necrosis</td>
<td>55</td>
<td>74.3</td>
</tr>
<tr>
<td>Pulp canal obliteration</td>
<td>17</td>
<td>24.3</td>
</tr>
<tr>
<td>Ankylosis</td>
<td>32</td>
<td>44.4</td>
</tr>
<tr>
<td>Inflammatory root resorption</td>
<td>29</td>
<td>39.4</td>
</tr>
<tr>
<td>Surface resorption</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>Bone loss</td>
<td>3</td>
<td>4.1</td>
</tr>
</tbody>
</table>

### Results, ten years after the injury

<table>
<thead>
<tr>
<th>Number of diagnosed events</th>
<th>Estimated risk (%)</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth loss</td>
<td>28</td>
<td>49.3</td>
</tr>
<tr>
<td>Pulp necrosis</td>
<td>55</td>
<td>74.3</td>
</tr>
<tr>
<td>Pulp canal obliteration</td>
<td>19</td>
<td>&gt; 25.7</td>
</tr>
<tr>
<td>Ankylosis</td>
<td>33</td>
<td>46.3</td>
</tr>
<tr>
<td>Inflammatory root resorption</td>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>Surface resorption</td>
<td>3</td>
<td>4.4</td>
</tr>
<tr>
<td>Bone loss</td>
<td>3</td>
<td>4.1</td>
</tr>
</tbody>
</table>
The CODET$^2$ study by Jens Ove Andreasen

Data were collected from patients living in Copenhagen City who received emergency treatment at the Copenhagen University Hospital in the period between 1972 and 1991.

Treatment according to predefined principles. Dentists received 6 months training.

$^2$Copenhagen Dental Trauma
The CODET² study by Jens Ove Andreasen

Data were collected from patients living in Copenhagen City who received emergency treatment at the Copenhagen University Hospital in the period between 1972 and 1991.

Treatment according to predefined principles. Dentists received 6 months training.

Scheduled follow-up program: 3 weeks, 6 weeks, 3 months, 6 months, 1 year, 5 years, 10 years.

Each follow-up examination included a structured data sheet, radiographs and clinical photographs.

²Copenhagen Dental Trauma
### Clinical examination
#### Structured datasheets

<table>
<thead>
<tr>
<th>General information</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth specific information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>Dislocation</td>
<td>Mobility</td>
<td>Tenderness to percussion</td>
<td>Electric pulp test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Clinical examination

- **Dato**
- **Farve**
- **Dislokation**
- **Lesning**
- **Perkussions-emhed**
- **Vitalløse-prøve**
- **Ankylosation**
- **Fistel**
- **Gingivitis**
- **Niveau, (retraktion)**
- **Mesialt**
- **Facialt**
- **Distalt**
- **Lingualt**
- **Generelt**
- **Mobilis**
- **Percussion tone**
Radiographic examination

Andreasen 1981
Clinical photographs

A

B

Dias 24

Eva Lauridsen
Internet risk calculator

Inclusion criteria:

- Complete information from initial examination
- High compliance to follow-up program
- No previous dental trauma
- No large destruction of the crown
Internet risk calculator

Inclusion criteria:

▶ Complete information from initial examination
▶ High compliance to follow-up program
▶ No previous dental trauma
▶ No large destruction of the crown

With the resulting data base including 1282 patients and their 2191 traumatized permanent incisors we went to the biostatistical department ...
From our first meeting

Oral health researchers (Jens, Søren, Eva):

We would like to build a tree model!

Statisticians (Per, Thomas):

Very interesting! A tree model looks like this:
Tree model (first version)

- Data split into teeth with mature and immature root development at injury time
- Event-free survival probability
- Between injury day and up to 15000 days follow-up
From one of the next meetings

Oral health researchers (Jens, Søren, Eva):

Yes, but we want to include all the important factors and build a multivariable model

Statistician (Thomas):

Very well! A tree model can do this ...
Tree model (two variables)
Tree model (three variables)
Tree model (more variables)
Statistical background:

Classification trees are
- easy to generate using a computer
- easy to understand
- incorporate interactions

However, classification trees are
- weak, notoriously unstable models
- hard to validate
- cannot automatically adapt the situation at hand
Aim: to build a multivariable prediction model

Outcome: Time from injury until
- Pulp necrosis
- Pulp canal obliteration
- Ankylosis
- Infection related resorption
- Repair related resorption
- Marginal bone loss
- Tooth loss

Predictors:
- Mature/Immature
- Luxation injury
- Fracture injury
- Root fracture location
- Electric pulp test
- Dry time / wet time
- Loosening (Degree 0, 1/2, 3)
- Number of injured teeth
Treating the predictors: expert consensus

1. All analyses were carried out separately for mature and immature teeth.

2. For each injury type the oral health experts selected the relevant predictors.

3. Predictions of event risk are obtained based on the data in subgroups defined by the predictors.

\[1\text{ instead of allowing a brainless object (the computer) to find a model}\]
Treating the outcome: three challenges

Competing risks

Correlated event times

Censored data
How we dealt with competing risks

We estimated the **cumulative incidences** of healing complications in suitable competing risk models.

- Toothloss is a competing risk for all other healing complications.
- Pulp necrosis is a competing risk for pulp canal obliteration.
- Profylactic pulp extirpation is a competing risk for pulp canal obliteration and for pulp necrosis.
How we dealt with correlated event times

If two teeth are sitting in the same mouth then they share genes and exposure to oral conditions. Hence, for these two teeth the expected “time-to-healing-complication” is more similar than that of two teeth from different patients.

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We decided for the marginal approach of modelling. ⁴

- The univariate event time distribution of a single injured tooth is modelled.
- Predictions of event risk are given per tooth.
- Variance and confidence estimates were adapted.

What are censored data?

Outcome: time to healing complication

Interval censored

Right censored
How we dealt with right censored data

The risk of healing complication t-years after the injury (cumulative incidence) was estimated with

the Kaplan-Meier method (no competing risks)

and

the Aalen-Johansen method (with competing risks)
How we dealt with right censored data

The risk of healing complication t-years after the injury (cumulative incidence) was estimated with

the Kaplan-Meier method (no competing risks)

and

the Aalen-Johanssen method (with competing risks)

Both methods cannot handle interval censored data!
If a healing complication was diagnosed, its onset time was approximated as the midpoint between the dates of the current and the previous examination.
How we dealt with interval censored data (II)

In cases were two or more healing complications were diagnosed at the same examination, approximate event times were distributed in biological order.
Data base

The uncertainty principle of applied biostatistics says:

*A data base is a never perfect and a moving object, the position of which on a computer is often difficult to identify.*
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**FACT:** Between 2009 and 2012 we have worked with 11 different versions of the data base behind the Internet risk calculator.
Data base

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*A data base is a never perfect and a moving object, the position of which on a computer is often difficult to identify.*

**FACT:** Between 2009 and 2012 we have worked with 11 different versions of the data base behind the Internet risk calculator.

Our results are presently reproducible with the most recent version of the data base.
Results

For 7 different healing complications, the event risk was estimated for subgroups defined by:

- mature/immature
- luxation injury
- fracture injury
- injury specific factors

In each subgroup we predicted the 1, 3 and 10 year risk of healing complications. The actual follow-up was illustrated using histograms.

- No. graphs: 2708
- No. tables: 496
Example: mature teeth with subluxation and concomitant crown fracture injury

Numbers in study

- At injury: 62 Teeth, 52 Patients
- 1 year: 51 Teeth, 41 Patients
- 3 years: 25 Teeth, 20 Patients
- 5 years: 20 Teeth, 16 Patients
- 10 years: 11 Teeth, 9 Patients
Example: mature teeth with subluxation and concomitant crown fracture injury
Example: mature teeth with subluxation and concomitant crown fracture injury
Example: mature teeth with subluxation and concomitant crown fracture injury

![Tooth loss chart]

No events recorded during follow-up
Example: 10 year results for risk of pulp necrosis
Example: discriminative ability of electric pulp test

- Positive test

- Negative test
Discussion: Data and follow-up

The data collection started in the ‘70s. It is not totally clear and should be validated if the material is still representative for new cases.

Standards for treatment and monitoring may depend on the examining dentist and may have developed over the years.

This makes us less comfortable with presenting long term results.
Discussion: Data and follow-up

The data collection started in the ‘70s. It is not totally clear and should be validated if the material is still representative for new cases.

Standards for treatment and monitoring may depend on the examining dentist and may have developed over the years.

Cases with less than 10 months follow-up were excluded! This may have introduced a bias into the risk estimates (more close monitoring of severe cases)!

Some (selected?) patients where followed for 10, 15, 20 years. Differences between scheduled and actual examinations were not collected systematically . . .

This makes us less comfortable with presenting long term results.
Diagnosis of healing complications is difficult

For example: *pulp necrosis* was diagnosed if two of the following clinical signs were present:

- Grey discoloration of the crown
- Negative response to EPT after three months of observation
- Periapical radiolucency and/or infection related resorption

Discussion:

- Alternative definitions?
- Inter-observer differences
- Differences in monitoring frequencies
Limitations in the statistical analysis

- Event times were imputed as midpoints between examination dates
- We assumed no correlation between lack of compliance and the event risk
- We ignored the cluster-correlated data structure for the variance of the Aalen-Johansen estimate (no software available)
- We applied ad-hoc binomial confidence limits when there were no events
Modelling

We have not used parametric assumptions to estimate the risks of healing complications.

\[^5\] e.g. Cox regression, random survival forest
Modelling

We have not used parametric assumptions to estimate the risks of healing complications.

The general idea of multivariable prediction modelling: ⁵

To predict new cases we summarize what happened to previous similar teeth.

⁵e.g. Cox regression, random survival forest
Modelling

We have not used parametric assumptions to estimate the risks of healing complications.

The general idea of multivariable prediction modelling:

To predict new cases we summarize what happened to previous similar teeth.

But:

- Teeth in different subgroups are generally not comparable and have different predictors
- Any modelling would require a systematic validation study

\[^5\text{e.g. Cox regression, random survival forest}\]
Validation

Validation of the prognostic power of our Internet risk calculator in independent external data would be very useful.

Such a validation study could focus

- on differences between predictions and actual outcome for a single tooth
- on differences between predictions and actual outcome for all teeth in one patient
- the success of subsequent clinical actions
Summary

- The Dental trauma guide Internet risk calculator is freely available:

  http://www.dentaltraumaguide.org/

- The prognoses are based on the world's largest dental trauma database

- It is the result of 3 years intense collaboration between oral health researchers and statisticians

- All analyses were carried out with the free statistical software R