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Validation of the digital photographic assessment to diagnose traumatic dental injuries

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Abstract – *Introduction*: Alternatives for monitoring dental trauma in epidemiological surveys may be useful, as data collection of epidemiological investigation can be jeopardized due to several conditions. *Aim*: To investigate the validity of standard digital photographs to determine the occurrence of anterior dental trauma compared to the clinical examination in an epidemiological survey. *Methods*: Participants were children aged 8–12 years old attending both private and public schools; children were clinically evaluated for the assessment of dental trauma, and standard photographs were taken from maxillary and mandibular permanent incisors of each child. Validity was determined by calculating the percentages and respective 95% confidence interval of sensitivity, specificity, positive predictive value, and negative predictive value. Cohen's kappa statistic was also used. *Results*: A total of 412 children were included, totaling 3296 teeth assessed for dental trauma presence. The prevalence of dental trauma was 11.2% (95% CI 8.29–14.61) and 10.2% (95% CI 7.45–13.53), respectively, for the clinical examination and the photographic method. Agreement between the gold standard and the photographic diagnosis was good: 0.64 for the prevalence of dental trauma and 0.66 for diagnosis of dental trauma on a tooth basis. The diagnosis through the photographic method had higher specificity (96.7%) than sensitivity (65.2%). High positive likelihood ratio and low negative likelihood ratio were also observed. *Conclusion*: The photographic assessment method of dental trauma was valid and reliable as compared to the oral clinical examination.

Epidemiological studies related to anterior dental trauma have become more popular in the last years, and the prevalence of the outcome in children in these studies has presented a large variation from 2.4% (1, 2) to 58.6% (3). This wide difference in prevalence is attributed to characteristics of the populations where the studies were conducted and the diagnostic criteria of TDI (traumatic dental injuries) employed.

Several different indexes have been developed to diagnosis dental trauma in oral health surveys (4, 5). However, in several occasions, the data collection of epidemiological investigation can be jeopardized due to conditions related to the patient, examiner, and the clinical situation where the data were collected. Moreover, there are inherent difficulties in comparison with the examinations performed by different examiners in large or multicentric studies (6, 7), and there is a need of a considerable number of examiners for a large period of time (weeks or months) for these large epidemiological surveys (8). Therefore, there will be situations where the clinical examination would not be feasible (lack of professional, economic shortage) and alternatives for monitoring the oral health outcome will have to be employed.

One method that has raised the interest of epidemiologists in recent years is the photographic method (9). The main advantage to use intra-oral photographs in relation to the visual method is the possibility of storage of the image for further analysis, especially in longitudinal studies (10), as well allowing the comparison of data between different studies. This method has been demonstrated as a viable alternative for diagnosis of different conditions, including dental caries, dental restorations (10–13), enamel opacities (14, 15), and fluorosis (9, 16).

In relation to the diagnosis of dental trauma using photographs, there is one study already using this method (17). However, there is no information available regarding the validity of photographic method and its reproducibility when compared to clinical diagnosis. When testing a method, two main basic patterns should be considered, the validity and reliability, which have also been called accuracy and precision (18). Reliability indicated whether the test provides the same results when repeated by the same or different examin-

ers in different occasions. Accuracy refers to the degree the examination is appropriate to establish the value of what is being measured, observed, or interpreted. The validity informs whether the results represent the truth or how much is far from it (18).

Therefore, the aim of this study was to test the validity of the photographic method in relation to the clinical examination (gold standard) on the detection of anterior dental trauma.

Materials and methods

The present study was conducted with a sample of children who had been involved in a multidisciplinary school-based cross-sectional study evaluating several general and oral health outcomes (19). The participants of that study were all children aged 8–12 years old, attending both private and public schools in the city of Pelotas. Photographs of all children enrolled in 8 schools, randomly selected, of the 20 schools included in the survey, were taken for the present evaluation. The project was approved by the Human Ethics Research Committee of the Pelotas Federal University (protocol 160/2010) and by the Education Department.

Training exercise

To ensure study reliability, a training and calibration process was performed with the examiners responsible for conducting the oral examination prior to the fieldwork. Team members received a manual containing information regarding the instruments used. A mean Kappa value of 0.92 (range 0.89–0.95) was achieved for dental trauma assessment by the six examiners.

For diagnosis of dental trauma through photographs, a training exercise was also conducted prior to the study. Training for photographic diagnosis entailed the use of color photographs (different photographs from those of the main study) to show the major clinical characteristics of each situation of interest and the criteria to be considered in the differential diagnosis.

Clinical examination (gold standard)

Children were clinically evaluated by six postgraduate dental students using protective equipment (gloves, mask, and apron) and artificial light, following procedures recommended by the World Health Organization (WHO), performed the clinical examination in regular school chairs (20). Teeth were initially cleaned with dental gauze as and when necessary. The presence of dental trauma in the maxillary and mandibular permanent incisors was assessed using the O'Brien criteria (4). This index is widely utilized in surveys to identify the tissue involved (enamel, dentin, pulp). For each tooth, the examiner noted the type of injury, but the index does not allow discriminate diagnosis in soft issues.

Photographic method

After the clinical examination, photographs were taken by two previously trained dentists for the use of photographic equipment. Each child was positioned leaning against a wall contrary to the daylight, with the Frankfort maxillary plane parallel to the floor. A cheek retractor disinfected between children was inserted into the child's mouth and the child was asked to close the incisors in edge-to-edge contact. To obtain a reproducibility of the photographic conditions and minimize differences, a professional digital camera Nikon D40 (Nikon Co, Tokyo, Japan) with objective lenses Nikkor with zoom AF-S DX ED 18–55 mm f/3.5–5.6GII, set for 55 mm and using close-up lenses (+3), which were adapted in the anterior part of the objective lenses was used. A ring flash (Vivitar Macro 6000 AF C) was used to standardize the illumination condition. All photographs were taken with a fixed aperture of f/25 with fixed speed of 100, with autofocus selection. In relation to the quality and size of the images obtained, the modes FINE (high resolution) and LARGE were selected, where each photograph occupied 2.1 megabytes. All images were registered according to the specific patient and stored in a databank.

To standardize the size of each image, the Adobe Acrobat Photoshop CS5 software package was used, keeping the resolution in 300 dpi and a marginal cut in 25 × 19 mm. No correction in relation to color, brightness, and contrast was performed. Figure 1 shows the photograph of a child included in the study.

Three pediatric dentists who were not part of data collection in the field evaluate the photographs. The recorded images were projected by one of the authors, using Optima multimedia projector in a dark room, in the same hours for all examiners. The final photographic diagnosis was based on the classification agreement between at least two of the three dentists.

Both for the clinical and photographic examination, dental trauma was diagnosed on a tooth basis. For the individual, dental trauma was considered 'present', when an injury was detected in at least one tooth, or 'absent'.

Statistical analysis

Data were double typed in the Epi-Info 6.04 software and statistical analysis was conducted with STATA/SE

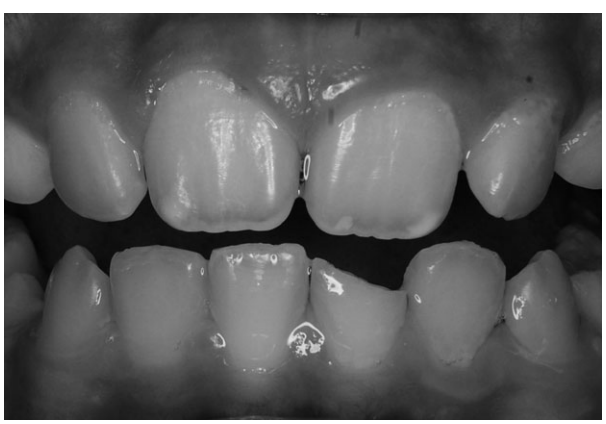

Fig. 1. Image showing the type of photographic image used to examine anterior dental trauma compared to clinical examination.

12.0 (Stata Corp, College Station, TX, USA). The prevalence of dental trauma according to the gold standard and to the photographic method with respective 95% confidence intervals (95% CI) was calculated. Level of agreement between the clinical and radiographic diagnose of dental trauma (for the individual and on a tooth basis) was assessed. The Cohen's kappa statistic was used to measure the reproducibility of the photographic method and the reproducibility of each of the dentists compared to the gold standard. Kappa interpretation was the following: ≤0.20 (poor), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.60–0.80 (good), and 0.80–1.00 (very good) 20. Sensitivity (SE), specificity (SP), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), negative likelihood ratio (NLR), as well as accuracy of the photographic method (with respective 95% confidence intervals) in comparison with clinical examination to detect anterior dental trauma presence were calculated.

Results

A total of 412 digital photographs were taken during the oral health survey. When observing the occurrence of anterior dental trauma, a prevalence of 11.2% (95% CI 8.3–14.6) was found in the clinical examination and a prevalence of 10.2% (95% CI 7.5–13.5) was observed in the photographic method.

Table 1 displays the agreement between the diagnosis from clinical examination (gold standard) and the diagnosis carried out using the photographic method for each one of the three dentists, as measured by Cohen's kappa. Agreement between each dentist and the gold standard was good. Agreement between the gold standard and the photographic method, which is the diagnosis that agreed with at least two of the three dentists, was also considered 'good' (0.64).

In Table 2, it is possible to observe the level of agreement in the diagnosis of dental trauma on a tooth basis, considering the type of injury diagnosed and a Kappa value of 0.66 was found. Differences were observed in relation to determination of the trauma, especially in relation to enamel fractures (33 and 38 in each method).

In Table 3, it is possible to see the values of specificity, sensitivity, positive predictive value, negative predictive values, and positive and negative likelihood ratios. The diagnosis through the photographic method had higher specificity (96.7%) than sensitivity (65.2%), and accuracy was 93.2%. Both, the PPV and the NPV were high (71.4% and 96.7%, respectively). A high likelihood ratio of a positive test (19.9) and a small likelihood ratio of a negative test (0.36) were achieved.

Discussion

To the best of our knowledge, this is the first study to validate the photographic method for dental trauma

Table 1. Level of agreement in the diagnosis of dental trauma occurrence, carried out by clinical examination (gold standard) and photographic examination for each one of the examiners and the final diagnosis (n = 412 children)

	Kappa value (SE)	Agreement with gold standard (%)
Examiner 1	0.62 (0.05)	92.7
Examiner 2	0.60 (0.05)	92.3
Examiner 3	0.61 (0.05)	92.2
Final diagnosis by the photographic method[1]	0.64 (0.05)	93.2

[1]Final diagnosis by the photographic method was based on the agreement of at least two of the three dentists.

Table 3. Sensitivity, specificity, PPV, NPV, PLR, and NLR for the diagnosis of dental trauma by photographic method compared with the clinical examination (gold standard). (n = 412 children)

		Clinical examination (Gold standard)		
	Dental trauma	Present	Absent	Total
Photographic method	Present	30	12	42
	Absent	16	354	370
	Total	46	366	412

Sensitivity: 65.2% (95% CI 50.8–77.3); specificity 96.7% (94.4–98.1); positive predictive value (PPV): 71.4%; negative predictive value (NPV): 96.7%; likelihood ratio of a positive test (PLR) 19.9 (23.4–127.6); likelihood ratio of a negative test (NLR) 0.36 (0.242–0.534).

Table 2. Level of agreement in the diagnosis of dental trauma on a tooth basis performed by clinical examination (gold standard) and photographic examination[1]. (n = 3296 teeth)

Clinical examination (Gold standard)	Photographic method								
	No trauma		EF		EDF		A		
	True negative	False negative	True positive	False positive	True positive	False positive	True positive	False positive	Total
No trauma	3223	0	0	17	0	3	0	0	3243
EF	0	13	19	0	0	1	0	0	33
EDF	0	5	0	2	12	0	0	0	19
A	0	0	0	0	0	0	1	0	1
Total	3223	18	19	19	12	4	1	0	3296

Kappa value: 0.66 (SE 0.01); EF, enamel fracture; EDF, enamel dentine fracture; A, avulsion.
[1]Final diagnosis by the photographic method was based on the agreement of at least two of the three dentists.

assessment. The overall results showed that photographic method could be used to detect TDI at the population level. The agreement in detecting dental trauma presence was good between each dentist and the gold standard, as well as the diagnostic obtained by agreement of the three dentists and the photographic method. Even though there are no universal criteria to define the ideal value of a valid method, some authors have defined a method as accurate when the sum of the sensitivity and specificity values is above 120% (18). In our study, this sum was far above 120 (161.9) demonstrating the high accuracy of photographic method. Also, in case of dental trauma type (enamel fracture, enamel dentin fracture), the Kappa value was 0.66.

The replacement of a more accurate form, for example, clinical examination, to establish determined outcome by a simpler one (photographic method), could be made taking in consideration that there is some risk of classification error (21). The risks should be known and considered low. A comparison of its validity against a gold standard is needed.

The use of digital imaging for the photographic method has many advantages, as highlighted by Martins et al. (9), justifying its use: It maintains confidentiality, as the teeth can be photographed; measurements of variation in density are possible with digital images and greater resolution increases the definition of the image; and the digital camera presents a better cost–benefit. Other advantages can be pointed out: It is a permanent record of enamel condition that can be compared with records made in laer evaluations; it provides a blind condition for the individual evaluation (for instance, the knowledge of socioeconomic level of the participant may interfere with the examiner's interpretation of physical signs depending on the condition assessed) (9).

The method, however, has certain limitations. A problem found in pictures of the anterior teeth is the specular reflexing and the shadow from the superior lip caused due to the flash position, which requires an examiner to be trained to perform the evaluation of standard photographs (16). To reduce this problem, in this study, the immediate evaluation of photographs was performed soon after they were taken, and in case of problem detection, a new snapshot was taken. Our study limitations also included those inherent in cross-sectional analyses of photographs, only crown fractures and avulsions being detected. Soft tissue injuries, luxation injuries, and root fractures were impossible to evaluate with this method. Noteworthy, the criteria used in this study, which were developed in the United Kingdom for the Children's Dental Health Survey in 1993, comprise one of the most widely utilized diagnostic indexes. It has well-defined diagnostic criteria and is easy to use in epidemiological survey.

Furthermore, we suggest that in future studies, the photographs be taken in more than one angulation for the same patient, thereby optimizing the diagnosis. Also, in the context of a large multidisciplinary study, investigating several different outcomes, such as in our study where 1210 children, from 20 public and private schools were enrolled, including oral health examinations, anthropometric measurements, and interviews in all children (19), the time needed for snapshot may be limited.

Of the total sample (1210), 153 (12.6%, 95% CI 10.8–14.6) suffered dental trauma, with a total of 175 traumatized teeth (22). Among the 412 children included in this evaluation, the prevalence of dental trauma was 11.2% through the clinical examination and 10.2% using the photographic method. The diagnosis with the photographic method had higher specificity (96.7%) than sensitivity (65.2%). A possible explanation for this is the fact that it was difficult to diagnose trauma in case of aesthetic restorations to treat dental fracture. In few cases, children who had dental fractures treated with composite restorations were considered free of trauma.

Such finding could be due to the fact that during clinical examination, the examiner had information given by the children about the injury, while during photographic examination, the examiner was blinded and had no information about the children's oral health history. This could also difficult the correct diagnosis of avulsion, when the anamnesis would be important. To avoid this problem, information regarding dental trauma history should be made accessible to examiners.

On the other hand, in the Elwood study conducted to analyze development defects of enamel on Brazilian school children, there was a tendency for subjects to be given a higher score using photographs (23). Martins et al. (9) assessed the agreement in the diagnosis of dental fluorosis performed by a standardized digital photographic method and a clinical examination (gold standard); they found a prevalence of dental fluorosis higher in the clinical examination (49%) compared with the photographic method (36.7%). The photographic method presented higher specificity (96%) than sensitivity (70.8%), demonstrating its validity to detect dental fluorosis. Regarding likelihood ratios, positive likelihood ratio is the probability of positive test in those with disease (true positive) divided by the probability of positive test in those without disease (false positive), and negative likelihood ratio is the probability of negative test in those with disease (false negative) divided by the probability of negative test in those without disease (true negative). In general, a useful test provides a high positive likelihood ratio and a small negative likelihood ratio (24), as observed in our study.

In relation to the agreement level observed when evaluating the type of dental trauma, a kappa value of 0.66 was found, which could be considered adequate. Some disagreements were observed in the classification, mostly in relation to enamel fractures. Enamel fractures are the most frequently found trauma in anterior teeth, and in the majority of the cases, they do not require any treatment (22). Therefore, the disagreement could be expected in such situations where the fracture is restricted to small portion of enamel loss.

Another disadvantage is the need of an appropriate professional digital camera, which involves a relatively high cost for initial acquisition and proper training of operator for adequate use (9). The cost of the equipment is approximately eight times higher than of

conventional cameras (16). On the other hand, the cost to maintain an experienced fieldwork team in large studies is much greater. In addition, once the camera is acquired, it can be used in other epidemiological and clinical studies.

Also, a snapshot can, in several cases, replace the clinical examination made by a dentist, especially in areas difficult to access or with a lack of dental team. A trained operator could take the standard snapshots with the professional digital camera for later evaluation by a dentist. For example, Moncada et al. (12) found that the digital photographs could be a simple and low cost method to perform clinical evaluation of dental restorations, avoiding the need for having a professional team in the dental offices to do evaluation of restorations *in loco*.

In our study, we found an adequate level of agreement between photographic method and clinical examination for anterior dental trauma. Similar results were found by Elwood when comparing clinical examination and digital photographs to detect the prevalence of fluorosis in a population, with kappa value of 0.63. Contrarily, when comparing the two methods of analyzing the presence of DDE (development defects of enamel) in primary teeth, Chen et al. found a fair to moderate result, with Kappa values ranging from 0.25 to 0.51. The photographic examination detected significantly more DDE than the clinical examination regardless of age group and type of DDE. The intra- and interexaminer reliability of the photographic method were excellent with Kappa values ranging from 0.638 to 0.927 (25). Boye et al. (11) compared caries information obtained from a full mouth visual examination with caries data obtained from intraoral digital photographs of index teeth in children aged between 5 and 10/11 years and found an intrarater reliability almost perfect agreement for all the examiners using the different examination and assessment methods. Moncada et al. (12) compared the performance of a direct clinical evaluation method with an indirect digital photographic method and observed a moderate agreement between the two methods.

In practical terms, one important question is to determine whether the outcome is present in the individual or not, that is, determine the PPV, also known as probability post-test (21). The prevalence of the outcome has more influence on the PPV than on SE and ES. According to our data, the probability to identify dental trauma in the photographic method as compared to clinical method was high, above 70% (71.4%).

The development of an appropriate photographic method for epidemiological studies to diagnose different dental outcomes (fluorosis, DDE, caries, quality of restorations, and dental trauma) is the current focus of interest. At least in relation to anterior dental trauma, the findings of our study are promising, showing that the method has an adequate validity as an alternative method to the clinical examination.

Conclusions

Within the limitations of our study, the photographic assessment method of anterior dental trauma showed to be valid and reliable as compared to oral clinical examination performed in a school-based epidemiological survey.

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