Improving radiographic diagnosis of pulpo-periodontal complications in primary molars by training: application in education and clinical research

Michèle Muller-Bolla*[1, 2],Clara Joseph*[1, 3], Nicola Innes[4], Elody Aïem[1, 3], Serena Lopez[5], Lamin Juwara[6], Ana Miriam Velly[6]

[1]University Côte d'Azur, Centre Hospitalier Universitaire de Nice, Department of Paediatric Dentistry, UFR Odontology, Nice, France
[2]Laboratory URB2i EA - 4462, University of Paris, France
[3]Laboratory MICORALIS EA - 7354, University Côte d'Azur, France
[4]School of Dentistry, Heath Park, University of Cardiff, Cardiff, Wales, United Kingdom
[5]Faculty of Dentistry, Department of Paediatric Dentistry, Unité d'investigation Clinique en Odontologie (Uic11). Centre de Recherche en Education de Nantes (CREN EA 2661). University and Hospital of Nantes, Nantes, France
[6]Faculty of Dentistry, University of McGill, Dental Department of Jewish General Hospital, Montréal, Canada
*Michèle Muller-Bolla and Clara Joseph should be considered joint first author

ORCID

Elody Aïem https://orcid.org/0000-0003-1306-783X

Nicola Innes https://orcid.org/0000-0002-9984-0012

Clara Joseph https://orcid.org/0000-0002-91004-6163

Serena Lopez-https://orcid.org/0000-0003-2358-8428

Michèle Muller-Bolla https://orcid.org/0000-0003-2811-5339

Ana Miriam Velly https://orcid.org/0000-0003-3125-1884

Correspondence
Ana Miriam Velly, Faculty of Dentistry, University of McGill, Dental Department of Jewish General Hospital, Montréal, Canada.
Email: ana.velly@mcgill.ca

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Abstract

The objective of this descriptive study was to assess an original learning intervention to train students and paediatric dentistry teachers in radiographic diagnostic accuracy of pulpo-periodontal complications in primary molars.

M&M: The learning intervention was based on 250 different randomly ordered radiographs of primary molars within three quizzes (A, B, C) for 5 sessions (S): quiz A (50 x-rays), B and C (100 x-rays) were respectively completed in S1 to assess the extent of agreement with 5 experts' diagnoses, in S2 and S3 (B at days 8 and 23), and in S4 and S5 (C at days 90 and 105). During S1 and at the end of S3 and S5, the participants (48 students, 16 teachers) were informed of correct diagnoses. A satisfaction questionnaire was completed by all the students. Alongside the descriptive analyses, Generalized Linear Mixed Model (GLMM) analyses assessed the odds of participants' correct diagnosis over study duration.

Results: At S1, the odds of diagnostic accuracy among students were significantly lower than among the teachers. After receiving feedback at S1, GLMM analyses showed that among all the participants accuracy improved over time with the odds of correct diagnoses higher in S2-5 compared to S1; and there were similar increases across sessions between teachers and students, except in S3, where the improvement among teachers tended to be greater than the students. All students were satisfied though one-third reported that quizzes with 100 radiographs felt too long.

Conclusion: The online case-based learning was a good training format for dental education.

Keywords: dental education, oral radiographs, primary molars, online learning, diagnosis accuracy

1 INTRODUCTION

An integral component of practicing dentistry in the era of minimally invasive dentistry, is the radiographic diagnosis and monitoring of carious lesion progression to identify pulpo-periodontal complications. The manifestation of these pulpo-periodontal complications of carious lesions are very specific when they affect primary teeth because of their morphology (thin pulp chamber floor, accessory canals connecting the pulp and the periodontal ligament),

histology (greater tubule diameter and higher density in the pulp chamber floor) and temporary characteristics (physiological root resorption). As a result, infection spreads quickly to, and bone loss occurs in, the inter-radicular area, which is one of the first signs of a compromised pulp.[1,2,3] Radiographic diagnosis of primary teeth is directly related to their close anatomical relationship with the follicle of the permanent successor. Thus, radiographic diagnosis in primary teeth can be difficult, and understanding the presentation does not follow on naturally from understanding the presentation in permanent teeth. This means that diagnosis of pulpo-periodontal complications of caries in primary teeth needs specific teaching for students in pediatric dentistry. In research, and more particularly in multi-center randomized controlled trials (RCT), evaluators need training and calibration in radiographic diagnosis in primary teeth to reduce evaluation bias and reach reproducible evaluations.[4,5] Inspired by the *e-calib* site proposed for training and calibration on *Fédération Dentaire Internationale* (FDI) criteria (www.e-calib.info in 2008), the purpose of this paper is to describe an original and simple learning intervention, based on quizzes of radiographs of primary molars by using Socrative web-sites to use in clinical research[6] and to test for dental education.

The objective was to assess an original learning intervention to train students and dentists in radiographic diagnostic accuracy of pulpo-periodontal complications in primary molars. In addition, we evaluated the student satisfaction with the learning intervention.

2 MATERIAL AND METHODS

This descriptive study received approval (R04-038) from the clinical research and *ad hoc* ethics committee of the CHUN (Centre Hospitalo-Universitaire de Nice) and it was registered in Heath Data Hub (MR004).

2.1 Participants

We enrolled: 1) 48 students with little clinical experience (4th-year dental students) in UFR Odontology of Côte d'Azur University (Nice); and 2) 16 dentists who were also teachers in Pediatric Dentistry from eight French academic hospitals of Bordeaux, Lille, Nancy, Nantes, Paris Bretonneaux, Paris Louis-Mourier, Strasbourg and Toulouse.

2.2 Quizzes

The complete procedure included three quizzes prepared by CJ on *Socrative Teacher* (https://b.socrative.com/login/teacher/): to assess radiography diagnostic accuracy and agreement among students and teachers (Figure 2). Quiz A included 50 different bitewings or periapical radiographs, and quizzes B and C included 100 new different radiographs of the same type. Size 0 (22x35mm) films (Dürr Dental) were used. On each radiograph, a primary molar with a crown fitted, which the assessor had to diagnose was identified by a star. In some cases, original stainless steel crowns (SSCs) were in place, and in the other cases CJ modified the picture by inserting a crown cropped from another radiograph. This was adjusted on the teeth using *affinity photo program* (Figure 1). Thus, all primary molars assessed had a preformed pediatric crown (PPC) to ensure that the diagnosis was not affected by observation of the natural crown (carious lesion, structural defect).

The radiographic diagnosis of pulpo-periodontal complications was based on the presence of radiolucency at the furcation, the periapical region or the root (internal or external pathological resorption). These radiolucencies are identifiable by an irregular periodontal ligament, or disappearance of bone trabeculations or enlargement of the root canal. [6,7]

The diagnosis in the three quizzes were previously validated through agreement on diagnosis of the images by an odd number of experts (CJ, EA, MMB, NI, and SLC). Due to disagreement, a second observation of a few radiographies was made, and no more than

three cases by quiz were discussed and resolved by consensus. None of these five experts were among the 16 teachers in Pediatric Dentistry from eight French academic hospitals.

For each of the 250 radiographs included in the three quizzes, the examiner (student or teacher) indicated his/her diagnosis (absence/presence of pulpo-periodontal complication). Thus, the study outcome was set as the diagnostic accuracy measured by the percentage of correct diagnoses by the participants (students or teachers) in reference to the experts' diagnosis (CJ, EA, MMB, NI, and SLC).

2.3 Exercises on Socrative website

We prepared five sessions on the Socrative Web-site (https://b.socrative.com/login/student/). The sequence of quizzes and their objectives are indicated in Figure 2.

Quiz A. On day 1 (session 1), all participants (students and teachers) completed quiz A (50 radiographs). The objective of this quiz was to assess whether each participant was diagnosing in agreement with the experts. The tooth to diagnose was emphasised with a star (Figure 1). After the participants scored each image, they were informed if the diagnosis was correct, and were presented with a commentary explaining the correct diagnosis.

Quiz B. At days 8 and 23 (sessions 2 and 3), all participants completed quiz B including 100 new radiographs in random order.

Quiz C. At days 90 and 105 (sessions 4 and 5), all participants completed quiz C including 100 new radiographs in a new random order.

At the end of the last session with quizzes B and C, respectively at days 23 and 105, each participant received a pdf file listing their answers with explanatory comments.

2.4 Satisfaction questionnaire

A questionnaire with two questions was completed by all student participants. A first question assessed the general opinion on this exercise with three options (waste of time, without opinion, satisfied). The second question assessed their interest in repeating exercises with four options (in favor of same quiz, different quizzes, both or only one quiz). Students could leave additional comments.

2.5 Statistical analysis

All statistical analyses were performed with R version 3.5.3. Descriptive data of the two groups of participants (students and teachers) characteristics are presented. Counts and proportions were used to describe categorical variables (gender and responses); mean and standard deviations for continuous variables (age).

We assessed the overall performance of the participants over the course of the study. We used Generalized Linear Mixed Model (GLMM) analysis to assess the odds of correct diagnosis of the participants (student/teacher) over study duration. The model adjusted for examination sessions (1-5), which was included as a fixed effect. To accommodate prior individual training and/or experience of the participant, we included a random effect term for the individual participants. We assumed a symmetric covariance structure between individuals over the duration of study. Learning curves are generated to describe the performance of student participants and teacher participants for the course of the study.

In addition, we assessed agreements among students and teachers at session 1 (Quiz A), using Fleiss' Kappa. We used a bootstrapped version of Cohen's kappa, generated from a resampled estimate of Cohen's Kappa, between randomly sampled student and teacher participants.

3 RESULTS

Out of 48 students recruited, eight did not agree to participate in all the sessions (only three sessions were obligatory as part of dental education), and three did not answer all questions in the quizzes. In Table 1, we present the diagnostic accuracy of the 37 students and 16 teachers participating in sessions 1-5.

A 'Fair agreement' was noted at session 1 before training among students (K = 0.30) and among teachers (K = 0.32). The GLMM analysis (Table 2), however, shows that among teachers the diagnostic accuracy improved since the odds of correct diagnoses were higher in sessions 2-5 compared to the first session. More specifically, among the teachers, there was an increase of 20% at session 2, 43% at session 3, 49% at session 4, and 42% at session 5 (in comparison to session 1). Moreover, these increments for the teachers were statistically significant in sessions 3 to 5. The odds of diagnostic accuracy among students was significantly lower than among the teachers at session 1 (46% less accurate than teachers). However, after

receiving feedback on their session 1 responses, students improved, when compared to the same teachers' odds (compared to session 1): at sessions 2 (2.02 times); 3 (1.24 times); 4 (1.35 times); and session 5 (1.36 times). The OR for session 3, however, was not statistically significant. In Table 2, we present the OR and associated p-values.

Figure 3 highlights the improvement in diagnostic accuracy of the participants over time. The probability of correct diagnosis of teachers and students improved significantly after session 1, maintaining similar magnitudes across sessions between teachers and students; session 3 was the exception, where the improvement among teachers tended to be greater than the students. The learning curves for teacher and student participants are presented in Figure 4 to highlight the change in the accuracy pattern of the participants over time.

Concerning the students' opinion of these exercises, all were satisfied. Almost all students showed interest in repeating the exercises: some were in favor of repeating the same quiz with same clinical cases (n = 21; 57%), a different quiz (n = 10; 27%) or both (n = 5; 13%); one student preferred to do only one quiz. One-third of the students (n = 12) found that quizzes that included 100 radiographies were too long.

4 DISCUSSION

This study shows that after training, students and dentists improved in their radiographic diagnosis of pulpo-periodontal pathology of primary molars on bitewing and periapical radiographs. The improvement was greatest in students after the session 1 with diagnostic accuracy remaining high in all study sessions afterwards.

In addition to the overall improvement in radiographical diagnoses of a crowned primary molar (Table 2, Figure 3), the diagnostic accuracy among teachers was high, ranging from 86 to 90% (Table 1). Among students, a significant improvement in diagnostic accuracy was observed among students changing from 77% to 89% (Figure 3). Apart from session 2, their improvement was lower than that of teachers ~~(Table 1).~~ In contrast, the higher improvement by students at session 2 after receiving feedback in session 1 is a promising result for education (Tables ~~1,~~ 2, Figures 3, 4). We suggest that the slight decrease in diagnosis accuracy at session 3 (by comparison to session 2) is explained by the longer time interval between sessions 2 and 3 (14 days) than among sessions 1 and 2 (7 days) (Figure 1). Our results also indicate that the training at session 3 was supportive of education since diagnostic accuracy remained high in study sessions 4 and 5 (Figure 3 and Table 2). It is already known that repetitive training is

important for students to learn and remember which elements to observe in radiographic diagnosis because of improvement in knowledge acquisition and a boost in knowledge retention.[8]

A 'Fair agreement' was found among teachers and students at session 1, before training. This is not surprising, emphasizing the importance of repeated exercises, particularly for inexperienced students. The fair agreement could be explained by the difficult examination conditions due to the presence of PPCs hiding the natural tooth crowns; the diagnosis could only be made on the basis of the pulpo-periodontal region. Radiographic examination of a "non-crowned" primary molar can reveal additional information, for example, the proximity of the deep carious lesion to the pulp chamber, and thus the increased likelihood of pulpal sequelae and pulpo-periodontal complications.[9] It has been suggested that the radiographic diagnosis should be carried out without prior information of the clinical diagnosis to prevent information bias. Indeed, in paediatric dentistry, there are always questions about the clinical symptoms given by the young child and family anyway. Consequently, in clinical practice, where there is uncertainty over the diagnosis, cases should be followed-up before a clinical decision is made.[10,11,12]

Moreover, the radiograph diagnosis of pulpo-periodontal complications in primary molars is complicated by physiological and pathological elements which can be difficult to discern and differentiate because of close anatomical relations with the follicle of the permanent successor. If frank interradicular radiolucency is the pathognomonic diagnostic element[13,14], other items can be sought as the most often periapical radiolucency and internal or external pathological resorption[15,16], or still sometimes, widened or irregular periodontal ligament / loss of lamina dura, disappearance of bone trabeculations, as it was noted in the different randomized controlled trials included in the systematic review of Smail-Faugeron et al[17] or others.[7] In clinical practice, the somewhat dense bone trabeculations are sometimes compared between similar tooth types of the child to help the dentists in the diagnosis. Moreover, external pathological resorption needs to be distinguished from physiological root resorption for accurate diagnosis.[18]

Our results are difficult to compare with previous studies since in our knowledge no studies assessed the diagnostic accuracy of pulpo-periodontal complications of carious lesions in the particular case of primary molars.[18] Most studies assessed the radiographic diagnosis accuracy of caries detection in permanent teeth[19] and rarely in primary teeth.[20] For studies

assessing education methods focusing on interpretation of bitewing or periapical radiographies, these are also rare and again, tend to be based on carious lesions in permanent teeth (not pulpo-periodontal complications of carious lesions in primary teeth).[21,22] Only some clinical studies used both radiographic and clinical diagnosis criteria of pulpo-periodontal complications of primary teeth, and due to the physiological peculiarities of primary teeth, radiographic outcomes were not always based on bivariate radiographic criteria (no changes / pathological changes)[15] ; they were grouped into four scores[10] corresponding to different clinical decisions (Table 3) with intermediate observation periods before the final therapeutic decision.

This study confirms students' positive attitude towards e-learning in oral radiology.[23] After a traditional radiology lecture course in the 2nd year (on permanent tooth carious lesions) and 4th year (on primary tooth carious lesions), this case-based learning format on the Socrative website was well received by students. Even though all students recorded their experience as satisfactory, some improvements to this education method can be put in place. Based on comments of one third of the students, the number of dental radiographies should be lower (100 was too high). Perhaps a smaller number of cases would improve participant' attention, as examining 100 teeth is time consuming. The individual commentaries on each case could also explain the moderate proportions of correct radiographic diagnoses in session 3, just 15 days after the session 2 due to participants' weariness and fatigue after such a long second exercise. As already noted[24], the students seemed to enjoy the challenge of interpreting the radiographic images without having clinical histories available. However, during the discussion at the end of the session 1, they were able to work up a different provisional diagnosis for a few cases when the dental histories were provided. This emphasized to the students the importance of collecting the patient's detailed clinical history before evaluating radiographs since a slight change in patient medical history could significantly impact interpretation of the lesion and alter the treatment plan.

Furthermore, a case-based learning format that emphasizes the development of students' clinical problem-solving skills where they increase in difficulty might maintain interest. Firstly, primary molar teeth without hidden natural crowns could be chosen for dental education. Next, primary molars with hidden natural crowns could be used to assess their learning. Finally, there could be development of a validated classification of radiographic diagnosis including different severity stages of pulpo-periodontal complications for primary

teeth. This staged method might increase the probability of correct diagnoses, but this approach would need to be investigated.

5 CONCLUSION

The online case-based learning based on five sessions with built-in feedback was a good training format for dental education for students and dentists, since the improvement of diagnosis accuracy for both groups remained over the duration of the study. The case-based learning format together with a complementary traditional lecture-based course emphasized the development of students' clinical problem-solving: it appeared to be an effective method and was appreciated by the students.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest to disclose regarding this study.

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TABLE 1 Population characteristics and unadjusted responses of participants

		Students (n=37)	**Teachers** (n=16)	**Overall**
Gender	Female, n (%)	13 (35.1)	5 (31.2)	18 (33.9)
	Male, n (%)	24 (64.9)	11 (68.8)	35 (66.1)
Diagnostic accuracy*	1 [x50]	1430 (77.4)	688 (86.0)	2118 (79.9)
Responses/Sessions	2 [x100]	3298 (89.1)	1408 (88.0)	4706 (88.8)
	3 [x100]	3174 (85.8)	1436 (89.8)	4610 (86.9)
	4 [x100]	3230 (87.3)	1442 (90.1)	4672 (88.2)
	5 [x100]	3212 (86.8)	1435 (89.7)	4647 (87.7)

Note: * number (%) of correct diagnoses

TABLE 2 Generalized Linear Mixed Model analysis of diagnostic accuracy ratio between participants (teachers or students). Odds ratios and 95% confidence intervals (CI) are presented

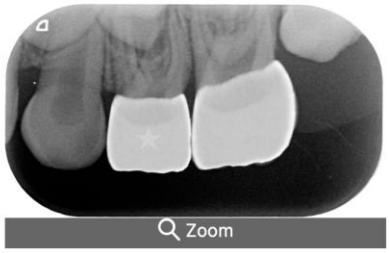
Session	Participants	Odds Ratios	95% CI	*P*-value
1	Teachers - reference	1	-	-
2	Teachers	1.20	0.93 – 1.54	.160
3	Teachers	1.43	1.11 – 1.85	.006
4	Teachers	1.49	1.15 – 1.94	.002
5	Teachers	1.42	1.10 – 1.84	.007
1	Students	0.54	0.41 – 0.72	<.001
2	Students	2.02	1.51 – 2.71	<.001
3	Students	1.24	0.92 – 1.66	.155
4	Students	1.35	1.01 – 1.82	.046
5	Students	1.36	1.01 – 1.83	.041

Note: Generalized linear mixed model analysis included diagnosis accuracy as dependent variable and participants (teachers or students) and sessions as the independent variables.

TABLE 3 Criteria for radiographic scoring: Criteria of Zum et Seale [10]

Criteria for radiographic scoring	
Radiographic Score	Definition
1 = No changes present	• Internal root canal form is tapering from the chamber to the apex • PDL and periapical regions are of normal width and trabeculation
2 = Pathological changes of questionable clinical significance	• External changes are not present (widened PDL, abnormal inter-radicular trabeculation or variation in radiodensity) • Internal resorption is acceptable • Calcific metamorphosis is acceptable and defined as: – Uniformly thin root canal – Shape (non-tapering) – Variation in radiodensity from canal to canal (one cloudier than the other)
3 = Pathological changes present, observe	• External changes are present, but not large: - Mildly widened PDL - Minor inter-radicular radiolucency with trabeculation still present - Minor external root resorption - Internal changes are acceptable, but should not be included unless an external change is also present
4= Pathological changes present, extract	• Frank radiolucency is present, endangering the permanent successor

FIGURE 1 Radiographic diagnosis of the crowned primary molar identified by a star

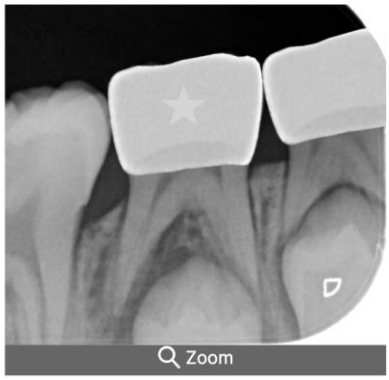


Give the radiographic score on tooth 64

A Score 0 : apical or furcation radiolucencies, radicular resorption (internal or external)

B Score 1 : healthy, physiological root resorption, ligament and/or trabecular bone structure with regular density pattern

SUBMIT ANSWER



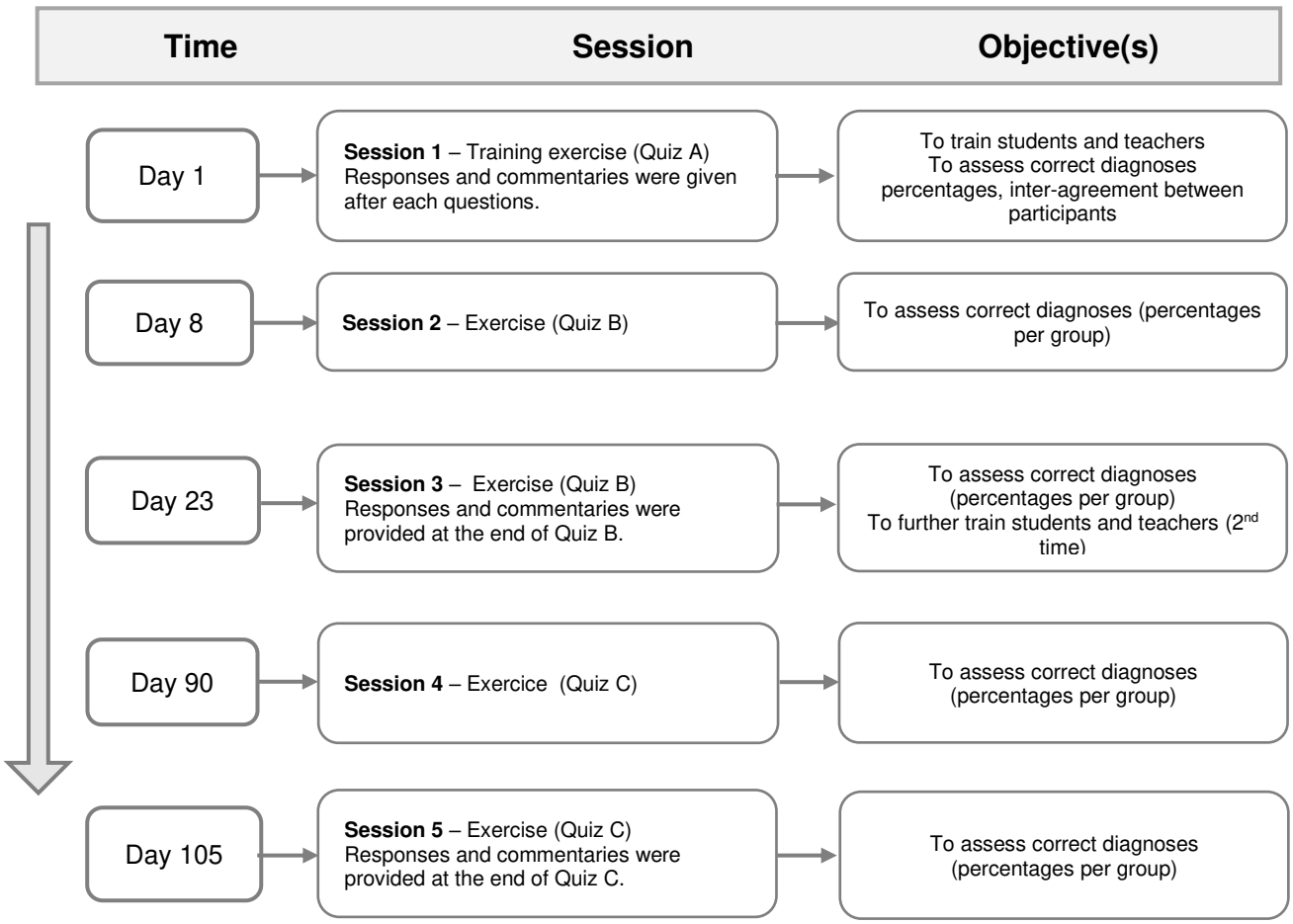
Give the radiographic score on tooth 85

A Score 0 : apical or furcation radiolucencies, radicular resorption (internal or external)

B Score 1 : healthy, physiological root resorption, ligament and/or trabecular bone structure with regular density pattern

SUBMIT ANSWER

FIGURE 2 Timeline and objectives of quizzes for training



250 different radiographies were used: 50 for Quiz A and 100 for both quizzes B and C

FIGURE 3 Marginal effects of interaction terms in the Generalized Linear Mixed Model of the diagnosis accuracy (correct diagnosis) of teachers and students

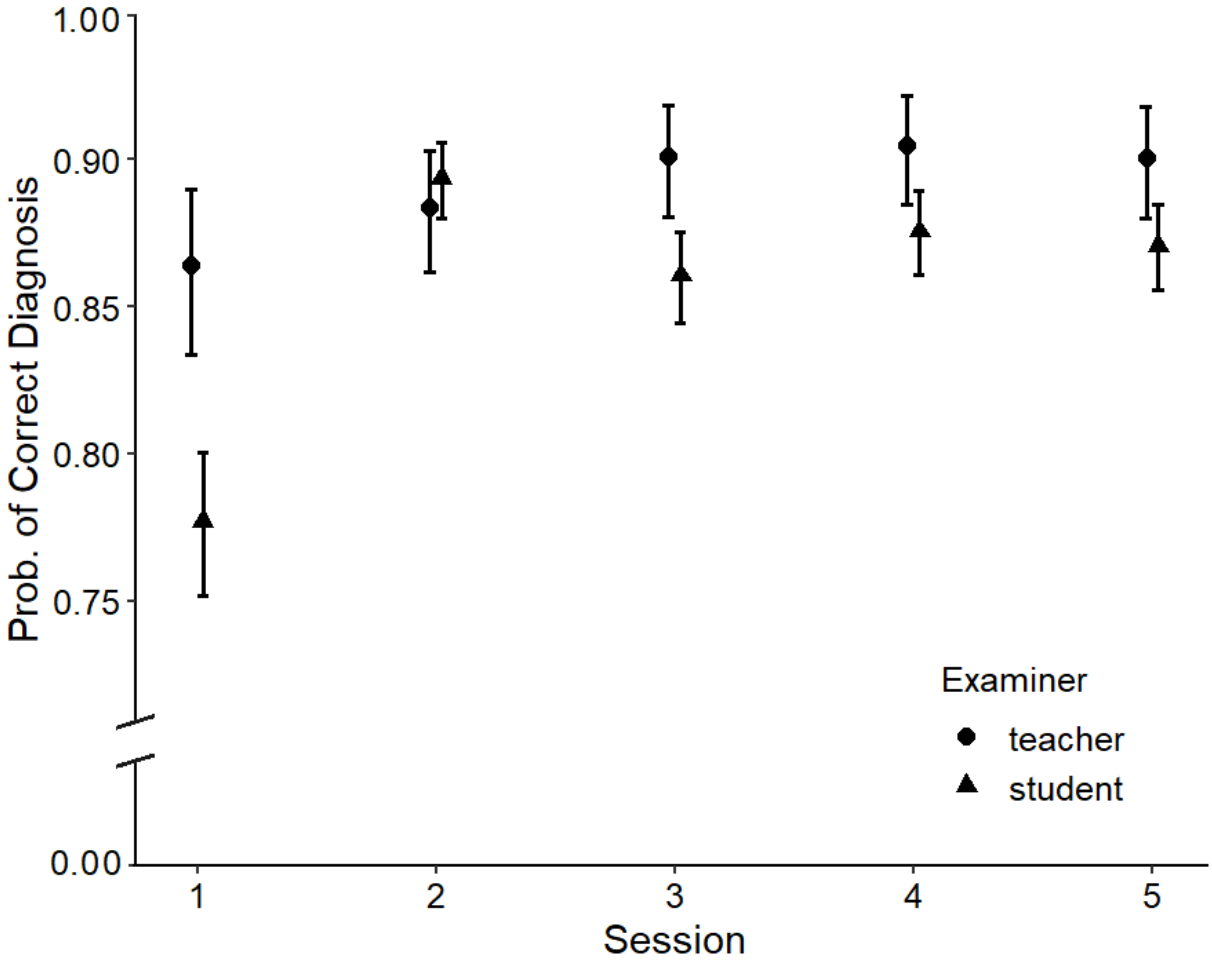


FIGURE 4 Learning curves for participants (teachers and students) in-terms of predicted diagnosis accuracy (correct diagnosis) over the duration of the study