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Comparison of conventional versus differential learning in periodontal scaling

Introduction: Aim of the study was to evaluate if differential learning of subgingival scaling improves the performance of dental students in a preclinical course compared to conventional learning.

Methods: Thirty-eight preclinical undergraduate students were randomly assigned to a test (differential learning, n = 19, females = 13) and a control group (conventional learning, n = 19, females = 14). Both groups were trained for 25 min daily over 10 days in subgingival scaling and root debridement on periodontitis models presenting either moderate (each n = 9) or severe periodontitis (each n = 10). Differential learning comprised 20 different movement variations (2/day) without any feedback, while conventional learning was based on repetition and correction of instrument handling and scaling technique. Practical training included subgingival scaling of all tooth types on phantom heads. Practical exams were performed after the training session (t1) and 6 (t2) and 24 weeks (t3) later and comprised subgingival scaling of a mandibular canine and first molar within 4 min. The percentage of cleaned root surfaces was assessed and statistically analysed by mixed effect linear regression models ($p < 0.05$).

Results: Differential learning resulted in a significantly better outcome than conventional learning (overall removal: 71.5 ± 16.5 % vs. 65.9 ± 17.9 %, $p = 0.04$), but performance decreased significantly over time in both groups ($p < 0.001$). The percentage of cleaned root surfaces depended on the kind of periodontitis model (moderate > severe), the kind of tooth (canine > molar) and on the root surface (verstibular > mesial = distal > lingual, $p < 0.001$).

Conclusion: Differential learning might increase basic scaling/root debridement skills of dental students; however, practical performance decreases over time if not further trained.

Keywords: learning; skill; scaling; variation

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1. Introduction

An essential component in periodontal education of undergraduate dental students is to achieve competence in performing supra-gingival and sub-gingival scaling and root surface debridement [15]. By eliminating bacterial deposits and metabolic products and generating a clean root surface, scaling and root debridement are essential in cause-related corrective and supportive therapy of periodontitis. Due to the complex anatomy of the roots, scaling and root debridement are technically challenging and require systematic training to improve effectivity [11, 14].

To achieve clinical competence in periodontal treatment, manual skills of dental students or dental hygienists are usually trained in a simulation environment using periodontitis models fixed in phantom heads. Systematic training of scaling and root debridement comprises repetitive practical procedures including use of curettes, sitting position of the operator and positioning of the patient [14]. Specific hand and forearm movements forming controlled exploring and working strokes of the instrument are practised. These skills lead to an effective and ergonomic treatment as well as a safe guiding of the instruments [6]. In contrast to this traditional learning strategy, which is based on repetition and correction of the target movement, the so-called "differential learning approach" was recently implemented in dental education [13]. Differential learning considers movement variations during skill acquisition rather than movement repetition as basis of motor learning [16]. Learning is assumed to be facilitated by discovering the space of possible performance solutions during high movement fluctuations and should therefore not be distracted by corrective advice [4, 17]. As a result of high movement variations, a self-organising process in the central nervous system is induced and a subject- and context-dependent optimal performance pattern is achieved [4].

Previous research has provided much evidence that differential learning of movement techniques is superior to repetition- and correction-orientated sport training (e.g. hockey [3], handball [19], soccer [18], shot-put [2]). Recently, differential learning was applied in a preclinical Course of Conservative Dentistry, where students had to train for the preparation of gold partial crowns. The performance was similar to the conventionally trained group immediately after the training session, but differential learning resulted in significantly better exam performance at the retention test after 20 weeks. In contrast, the performance of the control group trained by repetition, methodological series of exercise and correction of the preparations was significantly decreased indicating that mainly acquistion effects had occurred during the training phase [13].

As differential learning might increase manual skills of dental students, it might also be applied to the training of periodontal scaling. Therefore, this study aimed to compare conventional and differential learning of periodontal scaling in a preclinical dental course. The null hypothesis was that the performance (removal of simulated biofilm) of dental students was not different between both learning methods.

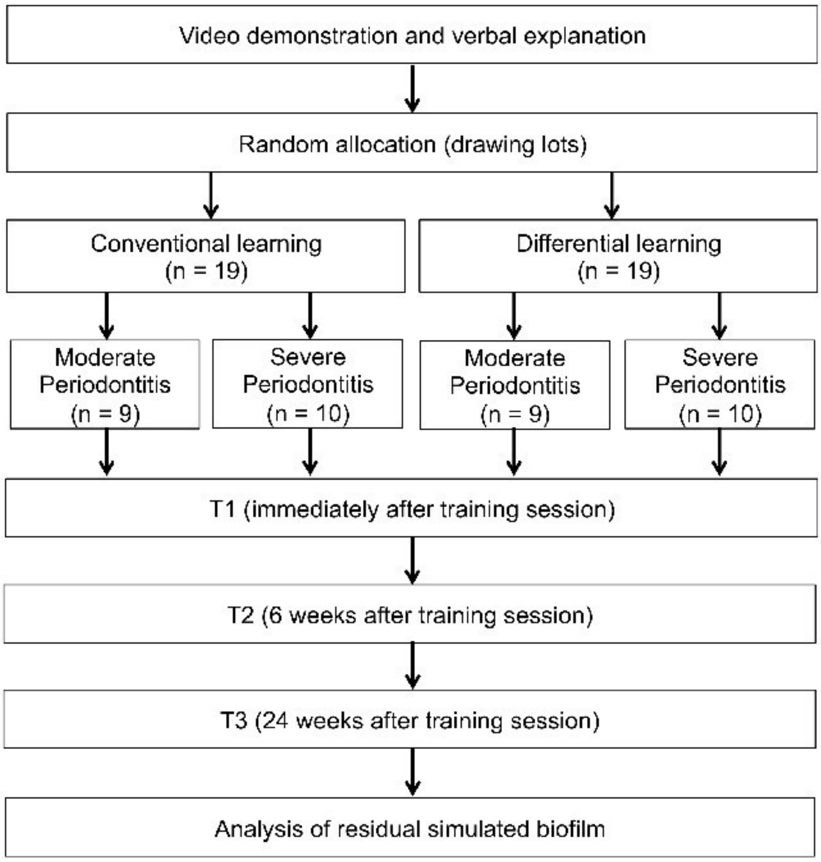

Figure 1 Study flow chart

2. Methods

This study was approved by the ethics committee of the University Medical Center Göttingen (reference number: 30/3/17). All participating students were informed about the study and gave written informed consent. The study flow chart is presented in Figure 1.

2.1 Participants

Thirty-eight third-year students (females: n = 27) of a preclinical Course in Conservative Dentistry (6th semester) were enrolled in this study. Students were inexperienced with regard to periodontal scaling and root debridement, as periodontology was not part of the undergraduate curriculum in the 1st to 5th semester. However, we did not control for relevant education (e.g. dental hy-

No.	Exercise
1.	Subgingival scaling in left position (right hand operators, “3 o’clock”) or right position (left hand operators, “9 o’clock”)
2.	Subgingival scaling while sitting on a gymnastic ball
3.	Subgingival scaling with one eye covered by an eye patch
4.	Subgingival scaling with goalkeepers gloves
5.	Subgingival scaling with left hand in left position (right hand operators) or with right hand in right position (left hand operators)
6.	Subgingival scaling after fixing the dominant hand with a resistance band (Thera-Band®, Artzt, Germany)
7.	Subgingival scaling while standing
8.	Subgingival scaling with bandage at the dominant hand
9.	Subgingival scaling on phantom head with reduced mouth opening
10.	Subgingival scaling in direct rear position (“12 o’clock”)
11.	Subgingival scaling with weight cuff (2kg) at the wrist of the dominant hand
12.	Subgingival scaling with earplugs
13.	Subgingival scaling with fixed feet
14.	Subgingival scaling with plaster cuff on the elbow of the dominant hand
15.	Subgingival scaling using steelball models instead of periodontal models
16.	Subgingival scaling with curettes with silicon-modified grips
17.	Dental gypsum vibrator machine is fixed to the phantom head, so that subgingival scaling is done during continuous movement of the phantom head
18.	Subgingival scaling the periodontal model outside the phantom head on the table
19.	Subgingival scaling using scalers (HuFriedy, USA S204S) instead of curettes
20.	Subgingival scaling with reversing glasses

Table 1 Presentation of variations/exercises during training of periodontal scaling

gienist). No specimen size calculation was performed as no valid estimates on the expected differences of scaling performance between the groups exist. Students were randomly assigned to 4 groups with regard to training intervention (conventional vs. differential learning) and periodontitis model (moderate vs. severe periodontitis). Each group comprised 19 students (differential learning: 13 females, 2 left-hander; conventional learning: 14 females, no left-hander).

Participation in the study was voluntary. Students who were repeating the preclinical course were not included in the analysis.

2.2 Periodontitis models and teeth

Periodontitis models (frasaco, frasaco GmbH, Tettnang, Germany) with simulated moderate or severe periodontitis were used and fixed in phantom heads. Differences between both models were mainly related to more vertical bone defects and furcation involvements as well as gingival recessions, hyperplasia and inclined teeth in the severe periodontitis model. Mean pocket probing depth amounted to 5.2 ± 1.3 m (range: 1 to 9 mm, moderate periodontitis model) and 5.6 ± 2.5 mm (range: 2 to 11 mm, severe periodontitis model), respectively.

Practical training included subgingival scaling of all tooth types. Each day, the accessible area of the root surface (from the artificial cemento-enamel junction to the bone level) was coated with a thin layer of nitrocellulose based red varnish (trend IT UP soft matte nail polish 020, dm, Germany) to simulate adhering biofilm. Thickness of the varnish layer was analysed in a preliminary test by cross-sectional microscopic analysis (Smartzoon 5, Zeiss, Jena, Germany) of 10 teeth and amounted to 65.9 ± 14.6 µm.

The models are made from hard plastic material and were covered by gingival masks (Frasaco, Tettnang, Germany) of elastic silicon to prevent visual control during instrumentation. Models were fixed in the upper and lower jaws of phantom heads (frasaco, frasaco GmbH, Germany).

2.3 Training intervention

Subgingival scaling and root debridement was performed with Gracey currettes 5/6, 7/8, 13/14 and 15/16 (HuFriedy, USA). Initially, all students received a video demonstration of instrument handling and ideal periodontal scaling technique on a periodontitis model with an additional verbal explanation. Moreover, all students were equipped with an application guide scheme presenting the correct handling of the instruments. The theoretical part also included information and pictures about the

Periodontal model	Tooth	Training approach	Timepoints		
			T1	T2	T3
Moderate Periodontitis	43	Differential learning	90.9 ± 4.6	80.9 ± 7.8	71.8 ± 12.2
		Conventional learning	83.6 ± 8.9	77.2 ± 11.6	67.5 ± 14.0
	46	Differential learning	76.9 ± 6.7	67.5 ± 21.7	65.1 ± 7.1
		Conventional learning	72.7 ± 9.2	70.5 ± 13.1	69.2 ± 15.7
Severe Periodontitis	33	Differential learning	82.9 ± 9.3	77.9 ± 11.0	78.7 ± 6.0
		Conventional learning	81.9 ± 5.8	70.9 ± 11.9	70.1 ± 13.2
	36	Differential learning	57.6 ± 17.3	60.6 ± 14.8	48.7 ± 16.1
		Conventional learning	52.4 ± 11.3	44.1 ± 11.8	38.9 ± 11.3

Table 2 Percentage reduction of simulated plaque (%, mean ± standard deviation) at the timepoints

root anatomy and roughness of different deposits. During the course and prior to each exam, instruments were sharpened by one supervisor.

After these initial video demonstration and prior to the first exercise students were separated to train either with the conventional or the differential learning approach. Practical training was performed for 25 min each day for 10 days. Students were either equipped with models with moderate or severe periodontitis; models were not changed during the study. During the training session all teeth were instrumented. The exercise aimed for removing as much simulated biofilm as possible on all root surfaces.

Students trained according to the conventional approach practised subgingival scaling with oral feedback and correction continuously given by 4 supervisors. Students trained by differential learning had to perform subgingival scaling with a total of 20 different exercises (Tab. 1). Each day, 2 different exercises were performed, the sequence of the exercises was randomly applied to the students. No further feedback was given to the students trained by differential learning.

2.4 Outcome

Summative practical exams took place at the end of the training period (t1, first day after end of training period) and 6 weeks later (t2). A formative exam (t3) took place 24 weeks after the end of the training period in the next semester. In all exams, the assignment was to remove simulated biofilm from the right mandibular canine and molar (43 and 46, moderate periodontitis model) or left mandibular canine and molar (33 and 36, severe periodontitis model), respectively, within 4 min. Mean pocket probing depth amounted to 3.5 ± 0.5 mm (left canine), 6.5 ± 1.8 mm (left molar), 5.3 ± 0.5 mm (right canine) and 5.7 ± 0.5 mm (right molar), respectively.

To assess the amount of residual simulated biofilm (%), digital photographs of all root surfaces (mesial, distal, buccal, lingual) were taken with standardized parameters (camera: EOS 700D, objective: 100 mm macro-zoom, Canon, Tokyo, Japan; camera settings: aperture F32, exposure 1/125, ISO 200, auto white balancing mode). Photographs were taken in dark ambience at a standardized distance. Standardized data masks comprising the maximum accessible/coated area of each tooth side were prepared and applied to determine the areas to be included in the analysis. Furcation areas were not analysed. The total areas of the coated surfaces amounted to 74.5 mm² (left canine), 115.0 mm² (left molar), 104.3 mm² (right canine), 122.6 mm² (right molar). The relative amount of residually stained surface was calculated with ImageJ (National Institutes of Health, Bethesda, USA) by one blinded examiner. Repeated measurements were performed to determine precision (coefficient of variation: 0.50 %).

Additionally, a short questionnaire to complete anonymously was given to the students at the end of the study. The questionnaire included 4 statements regarding the training session on a 6-point Likert scale from 'strongly agree' to 'strongly disagree'.

2.5 Statistical analysis

Mixed effect linear regression models considering the repeated measures were used to analyse the relationship between training method and removed simulated biofilm. As fixed effects learning method (conventional or differential), tooth type (canine or molar), tooth side (buccal, mesial, distal, lingual), periodontitis model (moderate and severe), timepoints, and the interaction between timepoints and learning method were entered into the model. The repeated measures were handled by modeling random intercepts and random

Parameter	Level	Reduction simulated plaque (%)	Estimate (%)	95% confidence interval	p-value
Training method	Conventional learning	65.9 ± 17.9			
	Differential learning	71.5 ± 16.5	5.8	0.4; 11.1	0.040
Periodontitis model	Moderate	74.5 ± 13.5			
	Severe	63.5 ± 18.9	-12.7	-17.8; -7.5	< 0.001
Tooth	Canine	77.8 ± 11.6			
	Molar	59.6 ± 17.6	-18.7	-20.8; -16.6	< 0.001
Tooth side	Distal	67.6 ± 24.8			
	Lingual	59.8 ± 22.2	-7.8	-10.7; -4.8	< 0.001
	Mesial	66.7 ± 23.3	-0.8	-3.8; 2.1	0.581
	Buccal	76.8 ± 14.5	9.2	6.2; 12.2	< 0.001
Timepoint	0 (t1)	74.1 ± 16.4	-0.4*	-0.6; -0.2	< 0.001
	6 weeks (t2)	68.5 ± 17.1			
	24 weeks (t3)	63.5 ± 17.4			

Descriptive statistics of reduction of simulated plaque (%, mean ± standard deviation) of single parameters as well as effect estimates, 95% confidence interval, and p-value from a multiple repeated measures mixed effect model., * per week

Table 3 Reduction of simulated plaque

slopes over time per student. Mann-Whitney-U tests were used to compare the student ratings across the learning approaches. The significance level was set to α = 5 %. The analysis was performed with the statistic software R (version 3.5.0, R Core Team 2018) using the R-package lme4 for the mixed effect linear regression [1].

3. Results

All students completed the study. However, one student in each group (conventional/differential learning) did not answer the questionnaire.

Students trained by differential learning removed significantly ($p = 0.04$) more simulated biofilm than students trained conventionally (Tab. 2). The percentage of cleaned root surfaces was depending on the kind of periodontitis model (moderate > severe), the kind of tooth (canine > molar) and on the tooth side (buccal > mesial = distal > lingual, $p < 0.001$, Tab. 3). The performance decreased significantly over time in both groups (Tab. 3); the interaction between timepoints and learning method was not significant. At the end of the study (t3), performance of students trained by differential learning was still better.

Students rated the differential learning approach more positively compared to conventional learning, but no significant differences between both groups were detected (Tab. 4).

4. Discussion

This study showed that differential learning resulted in slightly but significantly better root surface cleaning than conventional learning. Thus, the null hypothesis had to be rejected.

Students participating in this study were inexperienced in periodontal scaling. The dental curriculum in Germany is divided in 2 parts: In the 1st to 5th semester, basic scientific content is taught and practical courses in Technical Propaedeutics and Phantom Courses in Prosthodontics have to be completed. After passing the Intermediate Dentistry Exam, the preclinical Course of Conservative Dentistry (6th semester) has to be attended and patient-treatment courses are performed (7th to 10th semester) prior to the Dental Exam. Students participating in this study just passed the Intermediate Dentistry Exam, thus an equal level of practical experience can be assumed. Other possible confounders (age, gender, handedness, education) were not controlled in this study. However, an early study by Wilson and Husak [21] showed that cognitive knowledge, motor abilities, educational background and family demographics were not significantly predicting scaling and root planing performance.

Statement	Training approach	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
I was satisfied with the overall structure of the course	Differential learning	5.9 %	76.5 %	17.6 %	0	0	0
	Conventional learning	5.9 %	52.9 %	17.6 %	17.6 %	0	0
The course facilitated the development of manual skills and autonomous working	Differential learning	17.6 %	58.8 %	23.5 %	0	0	0
	Conventional learning	23.5 %	52.9 %	5.9 %	11.8 %	0	0
My manual skills were distinctly improved	Differential learning	11.8 %	23.5 %	52.9 %	11.8 %	0	0
	Conventional learning	23.5 %	23.5 %	29.4 %	5.9 %	17.6 %	0
The course was inspiring and motivating	Differential learning	0	52.9 %	29.4 %	17.6 %	0	0
	Conventional learning	5.9 %	29.4 %	35.3 %	11.8 %	11.8 %	5.9 %

Table 4 Percentage respondents in groups taught by differential or conventional learning. Note that only 17 students in each group answered the questionnaire.
(Fig. 1, Tab. 1–4: V. Hrasky)

Subgingival scaling and root debridement was performed on phantom heads equipped with periodontitis models to simulate clinical conditions. Periodontitis models are widely used to train subgingival scaling and root debridement [5, 11, 14], although the anatomic pocket structure is not simulated perfectly and a direct comparison to the clinical situation is not possible. Moreover, adaptation to the specific anatomy of the periodontitis model and repeated practicing on the same model might enforce adaptation processes and limit real learning of subgingival scaling [8]. Comparison to the clinical situation is further impeded by the use of artificial teeth, covered with nail varnish to simulate adherent subgingival biofilm.

Nail varnish differs from natural deposits such as calculus in texture and roughness. Removal is much easier. The use of artificial gingiva and the absence of patient-related factors, like tongue or mouth opening are also relevant differences. On the other hand, direct assessment of remaining subgingival biofilm is not possible under clinical conditions. Furthermore a high level of standardization of experimental conditions allows for detection of even small differences among groups. As done in previous studies [7, 10], two-dimensional analysis of root-surfaces was performed, taking into account that biofilm removal might thereby be underestimated in furcation areas.

Conventional training of subgingival scaling and root debridement was based on repetitive practising and correction of instrument handling and technique. On the other hand, differential learning was performed with movement variations and without feedback by the supervisors. Corrective feedback is not provided to prevent movement repetition and allow for the self-organising process [16]. The amount and frequency of movement variations was limited to 2 variations per day. Schöllhorn et al. [17] recommended to train beginners with reduced variations compared to advanced subjects as they usually present a higher inconstancy even when repeating movements. Although the students were inexperienced with regard to periodontal scaling, they already devolped some other fine motor skills during the first semesters. Therefore, 2 movement variations per day were chosen to be presented to the students of the test group. However, it has to be taken into account that the optimal range of variability in education of dental students according to the differential learning approach still needs to be investigated.

Students trained by the differential learning approach performed significantly better at all timepoints than students trained conventionally. Overall, the improved root surface cleaning immediately after the training period (t1) is comparable to pervious studies. Gartenmann et al. [5] investigated scaling/root planing skills of dental students after 8.5 h of manual training in 3 consecutive cohorts of a preclinical course. Instrumentation was performed with Gracey currettes, and scaling of a single-rooted tooth within a 5 min period resulted in 61.7 to 79.5 % artificial plaque removal [5]. Systematical training of hand instrumentation (6 x 2 h over 10 weeks) was shown to improve the effectiveness from about 55 to 70 % in the beginning to 85 to 90 % at the end of the training period [11, 14]. Retention of practical skills without further training sessions was not investigated in these studies. The present study showed that performance decreased for both learning strategies; potentially the initial improved root surface cleaning was attributed to acquisition effects rather than to real learning. The reduced performance of the conventionally trained group in the retention tests at t2 and t3 is in accordance to other studies investigating the retention of practical skills without further training [12, 20]. However, differential learning usually results in a stabilization or further improvement of the performance in the retention tests [3, 13, 16]. Potentially, either the overall training period was too short or the variability of practice too low [9]. Moreover, sufficient debridement requires not only fine-motoric skills, but also some basic knowledge about instrument handling and sharpening, i.e. choosing correct curettes for each side. While students trained conventionally were corrected frequently (e.g. when choosing an inadequate instrument), students trained according to the differential approach received no correction regarding instrument selection. This may explain why no stabilization or further improvement was seen in students trained by differential learning. Nevertheless, students trained accordingly to the differential learning approach performed better than conventionally trained students at both retention tests.

Overall, scaling performance was lower in severe compared to moderate periodontitis models, although pocket depth of the left molar was only slightly higher compared to the right molar and pocket depth of the left canine was even lower compared to the right canine. Potentially, lower left teeth are more difficult to be assessed by right-handers (majority of students in the present study, only 2 left-handers) than lower right teeth. As already shown in previous studies, effectivity was not only affected by pocket depth but also by root anatomy and tooth side. Scaling performance is usually better on single-rooted teeth and on buccal sides than on multi-rooted teeth and oral or proximal sides [7, 14].

Student ratings regarding conventional and differential learning were not significantly different, indicating that performance differences among groups are not related to motivational or structural differences. However, the overall positive ratings indicate that differential learning might be integrated into regular courses.

In conclusion, the present study showed that movement variations during training of scaling/root debridement might increase the overall performance of dental students compared to conventionally trained subjects. Further studies have to evaluate if increasing the variability of movements might further increase the effect of differential learning and if differential learning comes along with potential adverse effects, e.g. damages of gingiva or root surface.

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Conflicts of interest

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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