A systematic literature review of assessment feedback in Preclinical Dental Education

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Abstract:

Introduction: Development of evaluative judgement abilities through assessment and feedback strategies are crucial in students' progress to become self-regulated life-long learners. Dentists ability to appraise the quality of treatment provided to their patients starts with development of competences in a simulated preclinical training environment. However, the effectiveness of these assessment and feedback strategies is not well understood.

Material and methods: This literature review aims to identify assessment and feedback interventions and their effect on dental students' appraisal and psychomotor skills during preclinical training. A search of the electronic databases PubMed, Ebscohost (Dentistry and Oral Health), Scopus, Web of Science and EMBASE was conducted of studies published until October 2019.

Results: Twelve studies met the inclusion criteria. Two studies were randomised controlled trials and ten non-randomised studies. All studies included students' self-assessment and grading criteria as part of their feedback interventions. Feedback utilisation training was reported in 66% of the included studies. Evidence suggests feedback strategies improve psychomotor skills and increase agreement between students and teachers awarded grades. However, these improvements vary with the complexity of the task. Only one study shows self-directed learning significantly contributing to students' psychomotor skills improvement.

Conclusion: Although assessment and feedback are regarded as crucial for developing students' evaluative judgement capabilities to become self-regulated life-long learners, there is limited empirical evidence of the assessment and feedback conditions that enhance students judgement abilities, performance and self regulation. Further research is needed to investigate and compare the effect of different assessment and feedback interventions on students' appraisal skills, their impact on learning and self-regulation.

Key words: assessment, feedback, evaluation, learning, preclinical, psychomotor, self-regulation

Introduction

Assessment and feedback are reported to be crucial for developing students' judgement abilities that are essential to become self-regulated life-long learners¹. Self-regulation is a context dependent attribute that can be developed in a constructive process and constrained by features of the learning environment²⁻⁴. Self regulation is important for two main reasons: A) It empowers students to take control over their learning making them '*more persistent, resourceful, confident and higher achievers*'². B) It allows learners adapt to changes and maintain competency, an attribute expected of health professionals⁵⁻⁷.

There are numerous definitions of assessment depending on the context, functions and aims⁸. In the context of this study assessment refers to the appraisal of students work that generates information used to improve learning and teaching: Formative assessments⁹. A crucial aspect of formative assessment is feedback. Feedback is often used as a synonym for information passed from the instructor to the student. Although, there is no consensus in the literature for the definition of feedback¹⁰, it is agreed that feedback supports learning when students actively engage in the learning process and have opportunities to apply the information gained from it^{11 12}. Therefore, feedback could be defined as a dialogue between learner and instructor or peers where the learner not only receives comments (advice, criticism, opinion) but also pursues it; this process is not the end point but rather the beginning of learning.

It is further argued that assessment and feedback strategies support students independent and effective learning when they explicitly develop students' evaluative judgement¹³. Evaluative judgement is the "*capability to make decisions about quality of work of self and others*"¹⁴ and it underpins learners' ability to engage with feedback from multiple sources within and beyond university courses enhancing learners' ability to adapt and change tactics and behaviours¹⁴.

In the context of dentistry, the simulated clinical environment is where dental students begin to develop their psychomotor and appraisal skills that will enable learners to self-regulate. May et al.¹⁵ argue that self-assessment should be systematically taught to students because accurate self-assessment is an indispensable skill for dental practitioners to become life-long learners. Indeed, self-assessment activities are reported to enable learners to identify goals, recognise their current level of achievement and develop strategies to achieve these goals^{9,16,17}. Self-assessment activities are an essential aspect of any formative assessment because

it provides students with the opportunity to reflect on the quality of their work and learn in the process¹⁸.

Emerging literature in higher education, however, defines self-assessment not as a skill but as pedagogical strategy, along with feedback, rubrics, exemplars, and peer assessment, that can be adapted to exercise and develop students evaluative judgement.¹⁹ This dissonant definition lead us to investigate what assessment feedback strategies are being used in preclinical dentistry to enhance students' evaluative judgement.

There is currently a large body of literature on assessment and feedback in higher education in which dental education is underrepresented^{8,10,20,21}. Furthermore, to our knowledge, there are no reviews of assessment and feedback interventions used in dentistry. An improved understanding of feedback interventions used in pre-clinical dentistry is needed to inform educators and academics interested in developing feedback strategies that assist students learning. To this end, a systematic review of the literature will identify the utilisation and efficacy of assessment and feedback interventions in preclinical dentistry and their impact on students' psychomotor skills learning.

The objectives of this study are:

1. To determine feedback interventions used in preclinical dentistry.
2. To describe the characteristics of the interventions.
3. To find the outcomes of the feedback interventions

Methodology:

This systematic literature review followed the “Preferred Reporting Items for Systematic Reviews and Meta-Analysis” (PRISMA) guidelines²². The database used for this study were: MEDLINE (PubMed Interface), Ebscohost (Dentistry and Oral Health), Scopus, Web of Science, EMBASE. To time limit was set for the search up to October 2019. The focus search criteria or combination used were: Assessment, evaluation, feedback, dentistry, dental, education [Table 1].

The review used the PICO (Population, Intervention, Comparator and Outcome) to guide the criteria for inclusion and exclusion of studies. The population (P) included dental students in preclinical courses. Interventions (I) were all feedback exchanges generated within assessment of psychomotor skills, occurring within and beyond the immediate learning context, being overt or covert (actively and/or passively sought and/or received), and drawing from a range of resources¹⁰. The comparisons (C) were between groups, intervention and control, and within same group overtime. The primary outcome (O) measured was students’ psychomotor skills while the secondary outcome was students’ appraisal skills.

Selection procedure:

One author (xx) identified all titles and abstracts and removed the duplicates. After screening the abstracts and titles, inappropriate articles were removed based on the PICO inclusion criteria. The remaining articles were evaluated following the eligibility. The second author independently reviewed the remaining full text versions (xy). Disagreements between authors were resolved by consensus. The results of the screening process are shown in Figure 1 flow diagram.²³

Eligibility criteria:

All articles on assessment feedback interventions in preclinical dental education.

Inclusion criteria:

- Settings: Dental schools
- Participants: Dental students and teaching staff
- Study design: Randomised control trials and non-randomised studies.
- Language: English

- Year: Articles published up until October 2019

Exclusion criteria:

- Technology feedback: Studies with feedback provided by other means than human judgement e.g. haptic, scanners.
- Studies in clinical settings
- Assessment feedback interventions on aspects other than psychomotor skills. For example, knowledge
- Studies without students involved such faculty calibration studies.
- Theory: Publications describing assessment feedback methods
- Type of study: Descriptive studies without comparisons.

Data extraction and analysis

1. Study design features and risk of bias. There is ambiguity in the labels assigned to study design features. Consequently, the relevant data about study design features were collected using the Cochrane checklist for systematic reviews of non-randomised studies [Table 2] ²⁴. The check list further assisted the authors of this review to decide the eligibility of the studies. Risk of bias for randomised and not randomised studies were undertaken separately as recommended by the Cochrane guidelines ²⁴. For the randomised control trials the Cochrane risk of bias tool was used [Figure 2] and a different tool for non-randomised studies ²⁵ [Table 3]. No meta-analysis was undertaken because of the variety of interventions, study designs and type of measurements.
2. Feedback interventions components were classified and organised using Winston and colleagues' categories ⁸ [Table 4]. Descriptions of each components are Appendix 1.
3. The description of educational interventions was done collecting and collating data using a modified table from a publication on characteristics of educational interventions [Table 5] ²⁶.

Results:

Twelve studies met the inclusion criteria. All studies were published in dental or dental education journals. Nine in the Journal of Dental Education, two in the European Journal of Dental Education, one in the International Endodontic Journal.

Studies designs features

There were two main types of study: **A)** Studies comparing an intervention with a control group: Two randomised control trials (RCT) ^{27,28}, three non-randomised studies (NRS) ²⁹⁻³¹ and **B)** Studies comparing intervention outcomes within the same group overtime: Eight NRS ³¹⁻³⁷ ³⁸. [Table 1]. One prospective three arm study ³⁰, compared an intervention with a control group and within the same group overtime.

Risk of bias within studies

All studies presented risk of bias in at least one domain. Notably, blinding participants to the study as this is often a domain impossible to control in learning settings ^{30-32,34,35,37}. Students' previous skills or academic abilities ^{31-33,37,38} and measurement exposure ^{31,35} was the second most uncontrolled element of the studies [Figure 2].

Feedback interventions

Following Winston and colleagues' classification ⁸, feedback components were organised in four groups based on their conceptual similarities: 1) Internalising and applying standards, 2) Sustainable monitoring, 3) Collective provision of training and 4) Manner of feedback delivery. It is important to note that feedback components are not mutually exclusive and many of them are concurrently implemented [Table 3].

1. Internalising and applying standards

Feedback components in this group provide students with opportunities to become familiar with criteria standards and the process of appraising their own work and others ⁸.

Engaging with grading criteria: All studies reported using grading criteria in assisting students to recognize standards of quality during the appraisal process. Ten studies use criteria developed by teachers to produce a final grade by adding individual criterion's scores^{27-30,32,33,35-38}. Two studies allowed more flexibility. One study permitted teachers and students to award half marks or override the score³⁴ while in another study the criteria was created in collaboration with the students³¹.

Details on the validation and development of criteria vary from providing thorough details of the process to only making reference of their use^{28,35}. Huth et al³⁰ described the matrix analysis and criterion weighting worked out by collaborative efforts of four dental schools³⁰. De Peralta et al³⁷, report a similar collaborative and collegial participation in reviewing and updating of marking criteria used in their study³⁷. Majority of studies only displayed marking criteria rubrics with no reference to their development or validation^{27,29,30,32-34,36-38}.

Information on graders reliability using the marking criteria is also reported with different amount of detail. Some studies report a numerical value of reliability among graders^{29,30,33,34,36,39} while others mention the calibrating strategies used by the graders^{35,37,38}. [Table 4]

Self-assessment: All twelve studies included self-assessment as a component of the feedback intervention. Ten studies report students' self-assessment ability as changes in congruence between students' self-awarded grades and teachers' awarded grades^{27-30,32-37}. Two studies report students access to grading forms and self-assessment as component of the feedback intervention but without recording grades^{38 31}.

Peer assessment: Five studies reported students assessing peers' work as another source of feedback playing the role of promoting students' reflection and dialogue^{29,34-37}. When implemented, peer assessment appears secondary to self-assessment and the two studies that measured congruence between peer and teachers grades found students tend to overestimate their peers^{34,35}.

Dialogue and discussion: Dialogue and discussion support learners' goal setting, self-regulation and promote engagement with feedback⁸. Seven studies included dialogue and discussion. Three studies used only dialogue and discussion to improve students'

understanding of the marking criteria and standards^{28,29,36}. Interestingly, dialogue was also used among supervisors in calibration activities before assessing students work^{30,38}. De Peralta et al³⁷. used dialogue and discussion with supervisors to help students generate their own study plan. Manogue et al³¹. used dialogue among teachers and students to develop the criteria used to appraise students work.

2. Sustainable monitoring

This aspect of feedback allow students to record, monitor, and reflect on their performance and appraisal skills overtime⁸.

Action planning: Encouraging students to keep record of their progress is reported by Winstone et al⁸ to increase their engagement. Writing a self-generated study plan based on feedback from peer and instructors was used by students learning caries excavation³⁷. In two studies, learners had to write corrective actions after comparing their own work with exemplars of different quality^{29,36}.

3. Collective provision of training

This section includes strategies that provide group of students training and resources about the effective use feedback⁸. Although this training includes preparing students for their emotional response to feedback, this aspect was not present in any of the selected papers.

Feedback workshops: The description of students training to use and receive feedback vary in the level of detail provided. In one study, a teacher instructed students how to use the criteria³⁵. Three studies combined instructors' transmission and student active participation in dialogue with peer and supervisors to understand the marking criteria and practice how to use it.^{29,36 27}.

Exemplar assignments: The use of exemplars was aimed to help students understand the appraisal process. Three studies used photography and models of exemplars of different quality^{27,29,36}, another study utilised models only³⁰ and a fifth study used video clips to facilitate dialogue and discussion between students and teachers²⁸.

4. Manner of feedback delivery

This section refers to the mode of feedback delivery and its function⁸.

Formative assessment: The purpose of all selected studies was to generate feedback. Five studies have a summative component at the end of the intervention to evaluate its effect on students' performance^{33-35,37,38}. One study awarded students summative grades for self-assessment as an incentive to self-assess accurately³³.

Feedback without a grade: In only one intervention feedback did not have a numerical or scale grade³¹.

Tailored feedback: This component refers to students selecting the aspect of their work they would like to have feedback on. In one study, students could select which one of three amalgam preparations they wanted instructors to provide feedback²⁷. All other studies may have tailored their feedback, but this is not specified in the description of their methods.

Interventions outcomes:

Five interventions resulted in improved psychomotor skills and improved agreement between students and teachers' marks^{32 35 37 29,36}. A study found similar results for two surfaces amalgam preparations but no differences between intervention and control group in simple occlusal preparations for amalgam²⁷. Similarly, Huth et al³⁰ did not find significant differences on performance or agreement of student-tutor marks except in complex tasks where more intense feedback training resulted in significantly closer agreement between self and instructor grading. Shah's intervention, on the other hand, enhanced students amalgam preparations but did not result in significant differences of self-assessment abilities between the intervention and control group²⁸. Self-assessment scores were reported to be better predictor of students' performance than their teachers' scores by two studies³³ even after one of the studies corrected for regressions towards the mean³⁴.

Two studies did not measure the congruency between students and teacher grades. However, one study found that self-directed projects significantly contributed to students' wax carving improvement³⁸ and another reported increased student confidence after implementing a feedback strategy that required students self-assessment even when preclinical practice time was reduced³¹. In the later study, student performance was not measured. However, instructors reported students' performance was no different than before the intervention was implemented.

Discussion:

A limited number of studies were selected despite the ubiquitous use of assessment feedback in preclinical dental education. Even more surprising is the lack of reference to the use of feedback in preclinical dentistry in the broad higher education literature^{8,10,20}. This shows paucity of studies about assessment and feedback practices in preclinical dental education and the limited contribution of dental education into the broader higher education literature.

All selected studies reported using formative assessment strategies that included students internalising and applying standards by self-assessment and engagement with criteria standards as part of their feedback strategy. Not surprisingly self-assessment is central to all the feedback strategies. This reflective activity improves students' understanding of the appraisal process, ability to recognise and discriminate the quality of their work^{27,29,36} and aligns students and instructors objectives²⁸. Hence, students able to recognise quality, or lack of it, are more likely to improve their performance when reattempting the task.^{33,34}.

Changes in students' ability to judge the quality of their work is quantified as changes in congruence between students self-awarded grades and teachers' grades. Consequently, improvements in judgement ability are reported as agreement between students' self and teachers awarded grades^{27-30,32-37}. This indicator of judgement ability is problematic because of the low inter-rater reliability among instructors⁴⁰, underreported graders calibration¹⁸ and graders unconscious bias and heuristics in the appraisal process¹.

Quantifying this ability can be further clouded if regression towards the mean (RTM) is not controlled. Regression towards the mean is a statistical phenomenon where unusually large or small measurements are followed by measures close to the mean. This occurs when repeated observations are done in the same subject or unit⁴¹. Consequently, changes in measurements caused by this statistical phenomenon can be incorrectly interpreted as the result of an intervention. Furthermore, it is important to note that eight studies compare their outcomes to base line [Table 2]. Statistical testing against baseline is common in dental research. However, comparison to baseline studies overall have been criticized for presenting false positive results⁴².

Engaging with detailed grading criteria appears to solve many of the self-assessment issues by allowing analytic grading. This makes the appraisal process more transparent and fair to

students, and objective and accurate to teachers^{43,44}. Analytic grading breaks a complex task into single components and then sums them to a single final grade. This, as the name implies, allows analysis of supervisors' grading consistency and students' progress. Analytic grading, however, present several challenges⁴⁵. First, the sum of each criterion might not be a clear description of work quality since criteria boundaries might not be discrete and overlap. A criterion may be more important than others and, in more complex work, quality might be identified by an expert, the teacher, but not easily described in the criteria⁴⁵. Only two studies appear to put a strategy in place to address this limitation of analytic grading. Chambers et al³⁴ allowed students and teachers to override the grades according to their judgment and Geissler³² identifying the need for students to use their judgements to identify aspects of their work quality that are more important than others and hence carry more weight in the overall grade³². A second challenge is that grades in the form of a number, percentage or letter may be so encoded or cryptic that they become meaningless to students⁴⁶. And while student self-awarded grades may match with the their teachers, they may convey little about students' work quality or judgement abilities^{46,47}. Finally, criteria are open to interpretation and influenced by teachers' previous experience in the discipline, teaching environment and teachers marking experience^{40,48}.

The limitations of self-assessment and analytic grading should not discourage educators from implementing and measuring their interventions but rather make these problematic aspects of the appraisal process explicit to students and teachers. For instance, dialogue and discussion between learners and teachers can improve understanding of the grading criteria and its use^{30,32} and help them to plan strategies to improve future performance³⁷. More importantly, it will promote students' engagement with the feedback process⁸. Discussion and dialogue around one's own performance requires an environment of trust without fear of admitting mistakes^{30,33} and a teachers' culture of students actively involved in the feedback process through discussion and reflection³¹. This environment and culture can be nourished by explicitly training learners, and teachers, to understand the feedback process and the role they play in it⁸.

The information found in this review on assessment and feedback training varies from formally instructing students on the grading process to a more active involvement of students in the grading and feedback process. Notably by using exemplars. Judging the quality of exemplars gives a point of reference for meaningful feedback⁴⁹ because students can

experience and understand how instructors, experts, use criteria. This allows students to determine standards before their own work is assessed^{50,51, 27,29,30,36}. This is the reason assessing exemplars is also known as a '*feedforward*'⁵². Exposing students to examples alone may not enhance learning because students, particularly novice ones, may be unable to identify what is important or what is a good or poor work⁵³. It is in the dialogue with tutors and peers that students can build an understanding of what quality is, particularly when this understanding requires a tacit knowledge that cannot be captured in criteria⁵⁴. Dialogue around appraising exemplars also creates a community of practice whose participants will eventually share the same language and practices facilitating not only the acquisition of tacit knowledge and the interpretation of work quality but also strategies to achieve it⁵³.

Learners need to understand terminology and concepts used in feedback for it to be effective⁸. However, there is little mention on the relation between students ability to articulate technical information and their evaluative judgement ability and performance³⁶. Only one study reported on a feedback intervention where students wrote down an action plan with strategies to achieve the learning goals after engaging in dialogue with peer and teachers³⁷. The ability of students and teachers to articulate and communicate feedback and its relation with learning is underreported perhaps because of difficulties in capturing students' and teachers justification for their grades and strategies³⁷. This is a poorly understood aspect of feedback, one that could be facilitated by Information Communication technology (ICT).

Student self-regulation is another underreported aspect of feedback. Students' ability to assess their own strength and weakness as a learner is an essential aspect of self-regulation⁸. However, there is only one study reporting increased confidence among students actively engaged in self-assessment³¹. Despite the claims that assessment and feedback have a key role in developing learners independent learning, this review found little empirical evidence that this is the case. Except for Radjaipur et al.³⁸ who found that supplementary self-directed projects, without instructors' feedback, significantly counted for summative assessment improvements³⁸ demonstrating that students as early as first year, provided the right conditions, are capable to regulate their learning and thrive.

Although, it should be acknowledged that further research is needed to understand the effect of different assessment and feedback interventions on students' learning, this study recommends: a) Use marking criteria to facilitate dialogue among students and between

students and instructors. b) Implement self-assessment activities that encourages students to judge the quality of their work (what) and justify their judgement (why) rather than matching their grades with their peers and graders. c) Allocate time for dialogue between instructors and students where students can articulate, verbally or written, their evaluative judgement. d) Make instructors and students aware of aspects that interfere with human judgement such as unconscious bias and heuristics. e) Create the right conditions for students to regulate their own learning.

Conclusion:

Assessment and feedback are regarded crucial for developing students' evaluative judgement abilities to become self-regulated life-long learners. However, there is limited empirical evidence of the assessment and feedback conditions that enhance students evaluative judgement abilities, performance and self regulation and hence further research is needed.

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 50. Sadler DR. Specifying and Promulgating Achievement Standards. *Oxford Rev Educ*. 1987;13(2):191-209.
 51. To J, Carless D. Making productive use of exemplars: Peer discussion and teacher guidance for positive transfer of strategies. *J Furth High Educ*. 2016;40(6):746-764.
 52. Hendry GD, White P, Herbert C. Providing exemplar-based 'feedforward' before an assessment: The role of teacher explanation. *Act Learn High Educ*. 2016;17(2):99-109.
 53. Handley K, Williams L. From copying to learning: using exemplars to engage students with assessment criteria and feedback. *Assess Eval High Edu*. 2011;36(1):95-108.
 54. Carless D, Chan KKH. Managing dialogic use of exemplars. *Assess Eval High Edu*. 2017;42(6):930-941.

Table 1: Search strategy details

Database: PubMed

Search number	Query	Results
#14	(#9) AND (#8)	691
#13	(#9) AND (#7)	397
#11	(#9) AND (#6)	752
#10	((#9) AND (#8)) OR (#7)	688,037
#9	((#1) OR (#2)) AND (#3)) AND (#5)	1,149
#8	teaching	1,401,462
#7	learning	687,686
#6	education	1,728,872
#5	dentistry	595,499
#4	dental	576,057
#3	feedback	157,489
#2	evaluation	3,864,031
#1	assessment	3,270,975

Table 2: Design features of selected studies

Authors	Study label	Was there comparison?	How were participants allocated to groups?							Which parts of the study were prospective?				On what variables was comparability between groups assessed?	
		Between groups in different	Within same group overtime	Randomization	By other action of researchers	Student preferences	Time differences	Cluster (year)	Based on outcomes	Identification of participants	Assessment of baseline and allocation	Assessment of outcomes	Generation of hypothesis	Potential confounders	Baseline assessment of outcome variables
Feil & Reed ²⁷	RCT	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes	No	No
Sha et al ²⁸	RCT	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes	No	No
Knight et al ²⁹	NRS	Yes	No	No	No	Yes	No	No	No	Yes	No	Yes	Yes	No	No
Huth et al ³⁰	NRS	Yes	Yes	No	Yes	No	No	No	No	Yes	No	Yes	Yes	No	No
Manogue et al ³¹	NRS	Yes	na	na	Yes	No	Yes	No	No	Yes	na	Yes	P	na	na
Tuncer et al ³⁵	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	Yes	na	na
Radjaeipour et al ³⁸	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	P	na	na
Curtis et al ³³	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	P	na	na
Chambers & LaBarre ³⁴	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	Yes	na	na
DePeralta et al ³⁷	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	Yes	na	na

Knight et al ³⁶	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	Yes	na	na
Geissler ³²	NRS	No	Yes	na	na	na	na	na	na	Yes	na	Yes	P	na	na
P: Possibly, na: No applicable RCT: randomised controlled trial, NRCT: Non-randomised controlled trial, NRS: Non-Randomised Studies															

Table 3: Risk of bias assessment for included Non-Randomised Studies (NRS) ²⁵						
First author	Selection of participants	Confounding variables	Measurement exposure	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting
Knight ²⁹	Low	Low	Low	Low	Low	Low
Huth ³⁰	Low	Low	Low	Unclear	Low	Low
Manogue ³¹	High	High	Unclear	Unclear	Low	Low
Tuncer ³⁵	Low	Low	Unclear	Unclear	Low	Low
Radjaeipour ³⁸	Low	Unclear	Low	Low	Low	Low
Curtis ³³	Low	High	Low	Low	Low	Low
Chambers ³⁴	Low	Low	Low	Unclear	Low	Low
De Peralta ³⁷	Low	Unclear	Low	Unclear	Low	Low
Knight ³⁶	Low	Low	Low	Low	Low	Low

Geissler ³²	Low	High	Low	Unclear	Low	Low
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Table 4: Feedback intervention components ⁸

Intervention cluster	Intervention component	Selected studies (first author initial)											Total	%
		G ³²	M ³¹	C ³³	Ch ³⁴	R ³⁸	T ³⁵	F ²⁷	K ²⁹ &K ³⁶	H ³⁰	S ²⁸	DP ³⁷		
1.Internalising and applying standards	Self-assessment	x	x	x	x	x	x	x	x	x	x	x	12	100
	Peer assessment				x		x		x			x	4	33
	Engaging with grading criteria	x	x	x	x	x	x	x	x	x	x	x	12	100
	Dialogue and discussion	x	x			x			x	x	x	x	7	58
2.Sustainable monitoring	Action planning								x			x	2	16
	Portfolio													
3.Collective provision of training	Feedback workshop						x	x	x				4	33
	Feedback resources		x										1	8
	Exemplar assignments							x	x	x	x		4	33
4.Manner of feedback delivery	Formative assessment	x	x	x	x	x	x	x	x	x	x	x	12	100
	Feedback without grade		x										1	8
	Tailored feedback							x					1	8
	Presentation of feedback													
	Technology										x		1	8

X: Indicates the intervention component is present in the study

Table 5 Characteristics of selected studies

First author and year of publication	Setting	Students	Education providers	Intervention and comparison	Length of intervention	Teaching method
Geissler 1973 ³²	United Kingdom	n: 9 Age: not reported Gender: not reported	Faculty instructors	<i>Intervention:</i> Student self-assessment and instructor-student discussions. <i>Comparison:</i> Students progress measured in three different occasions.	4 months	Lectures, demonstrations and practical activities.
Manogue et al 1999 ³¹	United Kingdom	n: 98 Age: not reported Gender: not reported	Faculty instructors and lecturer.	<i>Intervention:</i> 3 lectures 8hrs tutorials, 5 h independent study time 21 h practical classes with self-assessment 5 h practical test with self-assessment. <i>Comparison:</i>	Intervention: 34 contact hrs. Original: 36 contact hours	Lectures, tutorials and practical activities.

				8 lectures, 39 h practical work, 3 h operative test.		
Curtis et al 2007 ³³	United States	n: 77 Age: Not reported Gender: 48 females, 29 males.	Faculty instructors	<i>Intervention:</i> Student self- and faculty assessment of prosthodontic exam. <i>Comparison:</i> Differences between first and second attempt on students' self and tutors' assessments	Two identical three hours examination spaced by 5 weeks	Instruction and a review of the evaluation format before first examination attempt.
Chambers and LaBarre 2013 ³⁴	United States	n: 157, 135 DDS and 27 international students. Age: Not reported Gender: not reported	Faculty instructors	<i>Intervention:</i> Two practical projects with students' self-assessment and tutors' assessments. <i>Comparison:</i> Student and faculty scores in first and second attempt	6 months	Practical projects: Self, peer and faculty assessments of each project

Radjaeipour et al 2015 ³⁸	United States	n: 562 (four consecutive classes) Age: majority in their 20s Gender: ratio male female +15%	8 to 12 faculty instructors	<i>Intervention:</i> Wax up project at home without assistance, wax up project with assistance in the laboratory, wax up practical projects (exams). <i>Comparison:</i> score of different projects.	3 or 4 weeks for home project and laboratory project. A total of 30 session preceded by 1hr lecture. 2.5 to 3 hrs for practical projects. Data collected for four years.	Lectures and laboratory sessions. Community driven e-learning platform, books, notes waxing schemes, grading forms.
Tuncer et al 2015 ³⁵	Turkey	n: 75	Faculty instructors	<i>Intervention:</i> Self- assessment: mid-term and final examinations. <i>Comparison:</i> Student and faculty scores overtime	A full term, no details given	Theory presentations, demonstrations, digital resources, course manual, practical assignments

Feil and Reed 1988 ²⁷	United States	n: 99 Age: not reported Gender: not reported	Faculty instructors	<i>Intervention:</i> Students exposed different quality preparations. Instructor centred + student centred. <i>Comparison:</i> Instructor centred	Two sessions, experimental group 45 minutes more than the control.	Student and teacher centred in the intervention, teacher centred instruction in the control
Knight et al 1990 ³⁶	United States	n: 86 Age: not reported Gender: not reported	Faculty instructors	<i>Intervention:</i> Recognition of ideal and variants using criteria with pictures and real models. Demonstration of evaluation and group discussion, production training, self- evaluation, discussion with peers, formative assessment. <i>Comparison:</i> Student and faculty scores overtime.	16 hours	Student centred, teacher supervision, television presentations

Knight et al 1990 ²⁹	United States	n: 13 Age: not reported Gender: not reported	Faculty instructors	<i>Intervention:</i> Recognition of ideal and variants using criteria with pictures and real models. Demonstration of evaluation technique and group discussion, production training, self- evaluation, discussion with peers, formative assessment. <i>Comparison:</i> Received verbal feedback with models on seven waxing projects over 13 hrs	13 hours	Not provided
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Huth et al 2017 ³⁰	Germany	n: 42. Gender: 17 male 25 female Age: not provided	Faculty instructors	<i>Intervention:</i> Tree training intensities: I no additional assessment of model, not discussion with peers, no feedback by instructor II one assessment of a test model, no discussion with peers, feedback by instructor III Two assessments of test models, discussion with peers, feedback by instructor. <i>Comparison:</i> Between interventions and Student and faculty scores overtime.	One term	Lectures on procedures. Interactive use of marking criteria on examples of different quality.
Shah et al 2015 ²⁸ Randomised controlled trial	India	n: 60 Age: average 19 years old Gender: female 47 male	Faculty instructors	<i>Intervention:</i> Feedback session aided with videotape (interactive feedback session) Student	1 hr 15 minutes	Video demonstration

		13			and faculty scores <i>Comparison:</i> control group without videotaped feedback session Student and faculty scores		
De Peralta et al 2017 ³⁷	United states	n: 104 Age: not reported Gender: not reported	Faculty instructors 8:1 student: faculty ratio	<i>Intervention:</i> Multisource assessment and reflective practice. <i>Comparison:</i> Student and faculty scores overtime.	Two weeks	Video instruction small groups	

Table 5 cont: Characteristics of selected studies

First author and year of publication	Discipline	Task	Measured Outcome	Type of measurement	Graders reliability strategies
Geissler 1973 ³²	Prosthodontics	Construction of complete and removable denture	Correlation between students and expert marks reported in %	For each criterion (12): Good, satisfactory and poor	Not reported
Manogue et al 1999 ³¹	Endodontics and fixed prosthodontics	Endodontics and crown preparation	Students self-reported confidence questionnaire. Problem solving ability	Questionnaire using a 1 to 5 (Strongly disagree to strongly agree) scale. Tutors comments.	Not provided
Curtis et al 2007 ³³	Prosthodontics	Setting maxillary denture teeth against standardised lower cast. Summative exam.	Correlation between students' self-assessment scores and teachers scores. Validated self-assessment: adjusted score for agreement between assessor and	Evaluation criteria: denture tooth position, arch form, midline positioning of teeth, contact in centric relation, and functional measures in working,	Reliability: Single evaluator evaluated 10 dentures twice $r = .77$

			student. Self-assessment as examination scores predictor	nonworking and protrusive movements. Binary: scale right/wrong	
Chambers and LaBarre 2013 ³⁴	Prosthodontics	A denture set up and, six months later, an immediate denture set up.	Correlation between student self- assessment score and teachers scores	Seven criteria using a 0 to 3 scale with a maximum summary score of 20 for the denture set up. Eighteen dimensions with Lower score 0 and higher 1 or 2. Maximum points value 25 for immediate denture.	Field consistency: faculty grade random work that graded previously r=0.575. Test Case consistency rating: nine projects evaluated by all faculty in evaluation exercise 0.65. Consistency between faculty 0.577

Radjaeipour et al 2015 ³⁸	Dental anatomy	Home project wax ups (7), laboratory projects (6), practical projects (4)	Products scores reported in percentages. Correlation between home projects, laboratory projects and practical projects	Standardised scoring rubrics.	Marking Protocol described. IRR or other measures of consistency not provided.
Tuncer et al 2015 ³⁵	Operative Dentistry	2nd year: Amalgam. 3rd year: Amalgam and composite.	Product scores, self and faculty graded reported in means	Criteria not specified, out of 100 points.	Experienced assessors (n=3). Level of agreement not reported
Feil and Reed 1988 ²⁷	Operative Dentistry	Class I and II preparations for amalgam	Agreement between students and faculty grades. Students performance.	Grades A, B, C and F	Intra rater reliability class I =.79 class II=.71
Knight et al 1990 ³⁶	Operative Dentistry	Class I for amalgam	Recognition skills (agreement with faculty pre and post products) and production skills	Recognition skills: 1 to 10 points. Production skills: 5 points referenced scale (8 criteria).	Faculty (2) agreement 82.3% Kappa=.75

Knight et al 1990 ²⁹	Operative Dentistry	Waxing life size plastic teeth	Recognition skills (agreement with faculty pre and post products) and production skills	Marking criteria	Perfect agreement evaluators 82.3% Kappa=0.65
Huth et al 2015 ³⁰ .	Restorative dentistry	Preparation for composite, composite filling, preparation for gold, preparation for ceramic, trepanation, root canal filling	Students ratings for each task and training intensity. Agreement student/instructor rates. Attitudes towards intervention.	Standardised assessment criteria. Likert 4 points scale	ICC: 0.944 for instructors 0.949 for students.
Shah et al 2015 ²⁸	Operative Dentistry	Class II preparation for amalgam	Mean grades self - assessment and tutors scores Questionnaire answers (Intervention group only)	A scoring check list (no details provided) 5 points Likert scale 1 strongly disagree to 5 strongly agree	Not reported

De Peralta et al 2017 ³⁷	Operative Dentistry	Caries removal	Product scores, self and faculty graded reported in percentages.	Standardised scoring rubrics. R Ideal, S acceptable, T acceptable modifications preferred, V unacceptable: Repeat procedure or major modifications necessary	Expert assessors were dentists and received 5 hrs of assessment training for caries specifically for caries removal. Level of faculty agreement not reported
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Figure legends

Figure 1: Systematic review flow chart of the literature search and selection process

Figure 2: Risk of bias for Randomised Controlled Trials

Appendix 1: Descriptions of each intervention component type

Appendix 2: Risk of bias assessment in included non-randomised studies

Appendix 3: Excluded papers with reasons

Appendix 1: Descriptions of each intervention component type ²⁵

Intervention cluster	Intervention component	Description
Internalising and applying standards	Peer assessment	Use of learners' own peers as a source of feedback and assessment, and/or assessing the work of one's peers as a means to engage with the expected standards
	Self-assessment	Requiring or encouraging learners to assess and prepare feedback on their own work, as a means to engage with the expected standards
	Engaging with grading criteria	Providing structured procedures or resources to help learners to understand grading criteria
	Dialogue and discussion	Requiring or encouraging learners to talk to their educators and seek advice, either as a substitute for, or in addition to receiving written feedback
Sustainable monitoring	Action planning	Forcing or encouraging learners to set themselves specific goals on the basis of their feedback, and to make clear action plans as means to work toward those goals
	Portfolio	Collecting learners' feedback together in one folder, or online profile, so that many sets of feedback can be viewed together and progress over time can be easily tracked
Collective provision of training	Feedback workshop	Structured sessions in which advice and/or activities are delivered to learners, intended to help them understand how to engage with and use feedback
	Feedback resources	Providing guidance documents that learners can use independently to improve their strategies for using feedback
	Exemplar assignments	Providing learners with real and/or constructed examples of previous assignments, as means to demonstrate optimal

		and/or suboptimal ways of completing their own assignment, and what makes these optimal or suboptimal
Manner of feedback deliver	Formative assessment/ Resubmission	Providing learners with opportunities to submit and receive feedback on noncredited work (as contrasted with credit-bearing summative assessment) and/or allowing learners to revise and resubmit their work after receiving summative feedback
	Feedback without a grade	Withholding grades from learners until they have engaged with the qualitative feedback
	Tailored feedback	Allowing learners to specify which aspects of their work they want to receive feedback on, and then giving feedback tailored specifically to their preferences
	Presentation of feedback	Changing the way in which feedback is presented to learners, through manipulations of visual layout, presentation medium, level of detail, and so forth
	Technology	Use of learning technologies to aid feedback use, including virtual learning environments, audio/video, computer-generated feedback, electronic voting systems, and Short Messaging Systems
Other	Other	Feedback interventions that do not fit into the preceding categories.

Appendix 2: Risk of bias assessment in included non-randomised studies¹

Knight et al 1990* (NRCT)		
Entry	Risk	Description
Selection of participants	Low	Intervention and control are from the same population of students and participated during the same time. All students failed to demonstrate mastery of waxing skills of the course before the intervention.
Confounding variables	Low	Students previous skills is disclosed. Investigators did not find significant differences between the two groups on entry GPA and academic records .
Measurement of exposure	Low	Data measured by trained experts
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	There is not missing data
Free of selective reporting	Low	Data reported is consistent with objectives and methods. The same data as a previous study is reported

Curtis et al (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively
Confounding variables	High	Confounding factors such students' general capability are not reported
Measurement of exposure	Low	Data obtained from trained grader (r=.77)
Blinding of outcome assessment	Low	"The faculty member who graded all maxillary dentures was mask to students' identity"
Incomplete outcome data	Low	One participant who did not complete second part of study was removed from study.
Free of selective reporting	Low	Data reported are consistent with study objectives

Chambers et al (NRS)

Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively
Confounding variables	Low	Confounding factor such students' general capability in laboratory and clinics are controlled
Measurement of exposure	Low	Comprehensive graders calibration strategies reported
Blinding of outcome assessment	Unclear	Graders could not see students' self-assessment but it is not clear if graders could identify participants
Incomplete outcome data	Low	Number of participants is available and baseline data did not differ from second part of intervention
Free of selective reporting	Low	Reported data align with objectives

Manogue et al (NRS)		
Entry	Risk	Description
Selection of participants	High	"Comparison of the attitudes of two successive cohorts of students towards...was undertaken in two successive years" First year was the control for the intervention in second year
Confounding variables	High	Confounding factors such students' general capability are not reported
Measurement of exposure	Unclear	
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	10% of questionnaires were not returned
Free of selective reporting	Low	Data reported are consistent with study objectives

Huth (NRS)		
Entry	Risk	Description
Selection of participants	Low	Intervention and control are from the same population of students and participated during the same time.
Confounding variables	Low	A three arms design provided a baseline of

		students' ability
Measurement of exposure	Low	Comprehensive measure instrument development and graders calibration strategies reported
Blinding of outcome assessment	Unclear	Graders were blinded to students' self-assessment but not clear if graders were blinded to students' identity
Incomplete outcome data	Low	There are no missing data
Free of selective reporting	Low	Data reported are consistent with study objectives

Tuncer (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively.
Confounding variables	Low	Students initial ability is controlled by baseline measurement.
Measurement of exposure	Unclear	Information limits to "course director calibrated supervising faculty"
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	There are no missing data
Free of selective reporting	Low	Data reported are consistent with study objectives

Radjaeipour (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and

		data were collected prospectively.
Confounding variables	Unclear	
Measurement of exposure	Low	Trained graders using standardise rubrics
Blinding of outcome assessment	Low	Grading was performed anonymously
Incomplete outcome data	Low	There is no missing data
Free of selective reporting	Low	Data reported are consistent with study objectives

de Peralta et al (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively.
Confounding variables	Unclear	
Measurement of exposure	Low	Graders participated in calibration activities and grading criteria is regularly updated.
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	There is not missing data
Free of selective reporting	Low	Data reported are consistent with study objectives

Knight et al* (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively.
Confounding variables	Low	Students previous skills is disclosed. Investigators did not find significant differences between the two groups on entry GPA and academic records.
Measurement of exposure	Low	Data measured by trained experts
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	There is not missing data
Free of selective reporting	Low	Data reported is consistent with objectives and methods. The same data as a previous study is reported

Geissler (NRS)		
Entry	Risk	Description
Selection of participants	Low	All participants are from the same population and data were collected prospectively.
Confounding variables	High	Confounding factors such students' general capability are not reported
Measurement of exposure	Low	Data measured by trained experts using rubrics
Blinding of outcome assessment	Unclear	
Incomplete outcome data	Low	There is not missing data
Free of selective reporting	Low	Data reported is consistent with objectives and methods. The same data as a previous study is reported

1. Kim SY, Park JE, Lee YJ, et al. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *J Clin Epidemiol.* 2013;66(4):408-414.

Appendix 3: Excluded articles and reasons of exclusion.

Author (first)	Title	Reason for exclusion
Roque et al ¹	Assessment of critical analysis competency in first year dentistry students using a self-evaluation tool	Does not include psychomotor skills
Best and Messer ²	Effectiveness of interventions to promote continuing professional development for dentists	Does not include psychomotor skills
Matheos et al ³	The effects of an interactive software application on the self-assessment ability of dental students	Does not include psychomotor skills
Moni et al ⁴	Using student feedback to construct an assessment rubric for a concept map in physiology	Does not include psychomotor skills
Zijlstra-Shaw ⁵	Assessment of professional behaviour - A comparison of self-assessment by first year dental students and assessment by staff	Does not include psychomotor skills
Broder & Janal ⁶	Promoting interpersonal skills and cultural sensitivity among dental students	Does not include psychomotor skills
Keselyak et al ⁷	Evaluation of Group Assessment in a Didactic Dental Hygiene Course	Does not include psychomotor skills
Cox et al ⁸	Making a mark--taking assessment to technology	Does not include psychomotor skills
González et al ⁹	A web-based learning tool improves student performance in statistics: A randomized masked trial	Does not include psychomotor skills
Hay et al ¹⁰	Non-traditional learners in higher education: comparison of a traditional MCQ examination with concept mapping to assess learning	Does not include psychomotor skills

	in a dental radiological science course	
Matthews ¹¹	Multifaceted strategy needed to improve dentists' adherence to evidence-based guidelines	Does not include psychomotor skills
Grieverson et al ¹²	Evaluation of workplace based assessment tools in dental foundation training	Does not include psychomotor skills
Holmes et al ¹³	Developing an assessment in dental public health for clinical undergraduates attending a primary dental care outreach programme	Does not include psychomotor skills
Jackson & Murff ¹⁴	Effectively teaching self-assessment: preparing the dental hygiene student to provide quality care	Does not include psychomotor skills
Barnes et al ¹⁵	Development of the Maturity Matrix Dentistry (MMD): A primary care dental team development tool	Does not include psychomotor skills
Edo et al ¹⁶	Web-based learning in undergraduate dental education: Bite-wing X-rays in paediatric patients	Does not include psychomotor skills
Priya et al ¹⁷	Continuous Assessment of Undergraduate Students at a Dental College in India	Does not include psychomotor skills
Sopka et al ¹⁸	Practical skills training influences knowledge and attitude of dental students towards emergency medical care	Does not include psychomotor skills
Zijlstra-Shaw et al ¹⁹	Assessing professionalism within dental education; the need for a definition	Does not include psychomotor skills
Haj-Ali & Al Quran ²⁰	Team-based learning in a preclinical removable denture	Does not include psychomotor skills

	prosthesis module in a United Arab Emirates dental school	
Jonas-Dwyer & Boyd ²¹	First reflections: third-year dentistry students' introduction to reflective practice	Does not include psychomotor skills
Winning et al ²²	Validity of scores from communication skills instruments for patients and their dental student-clinicians	Does not include psychomotor skills
Gatumu et al ²³	Evaluation of usage of virtual microscopy for the study of histology in the medical, dental, and veterinary undergraduate programs of a UK University	Does not include psychomotor skills
Leisnert ²⁴	Self-directed learning. teamwork, holistic view and oral health	Does not include psychomotor skills
Prior et al ²⁵	Evaluating an audit and feedback intervention for reducing antibiotic prescribing behaviour in general dental practice (the RAPiD trial): A partial factorial cluster randomised trial protocol	Does not include psychomotor skills
Sampaio-Maia et al ²⁶	Wiki as a tool for Microbiology teaching, learning and assessment	Does not include psychomotor skills
Yoshida et al ²⁷	Effectiveness of a simulated patient training programme based on trainee response accuracy and appropriateness of feedback	Does not include psychomotor skills
Al-Ansari & El Tautawi ²⁸	Comparison of Three Evidence-Based Practice Learning Assessment Methods in Dental Curricula	Does not include psychomotor skills
Al-Khotani et al ²⁹	Study on self-assessment regarding knowledge of temporomandibular disorders in children/adolescents by Swedish and Saudi Arabian dentists	Does not include psychomotor skills

Al-Rawi et al ³⁰	Development of a mobile device optimized cross platform-compatible oral pathology and radiology spaced repetition system for dental education	Does not include psychomotor skills
Alfaris et al ³¹	A one-day dental faculty workshop in writing multiple-choice questions: An impact evaluation	Does not include psychomotor skills
El Tantawi et al ³²	E-Assessment in a limited-resources dental school using an open-source learning management system	Does not include psychomotor skills
Sanchez_Sanhueza & Cabrera ³³	Praxis teaching in the ambit of learning assessment of endodontics in a Chilean university	Does not include psychomotor skills
Freda & Lipp ³⁴	Test-Enhanced Learning in Competence Based Predoctoral Orthodontics: A Four-Year Study	Does not include psychomotor skills
van Schaik et al ³⁵	Perceptions of Peer-to-Peer Interprofessional Feedback Among Students in the Health Professions	Does not include psychomotor skills
Wong et al ³⁶	Measuring interprofessional competencies and attitudes among health professional students creating family planning virtual patient cases	Does not include psychomotor skills
Arias et al ³⁷	New curricular design in biostatistics to prepare residents for an evidence-based practice and lifelong learning education: a pilot approach	Does not include psychomotor skills
Hong & Plugge ³⁸	Critical appraisal skills teaching in UK dental schools	Does not include psychomotor skills
Lipp et al ³⁹	Types of Feedback in Competency-Based Predoctoral Orthodontics: Effects on Students' Attitudes and	Does not include psychomotor skills

	Confidence	
Partido ⁴⁰	Dental Hygiene Students' Self-Assessment of Ergonomics Utilizing Photography	Does not include psychomotor skills
Zijlstra-Shaw et al ⁴¹	Evaluation of an assessment system for professionalism amongst dental students	Does not include psychomotor skills
Morales et al ⁴²	Validation of a self-assessment tool to measure critical analysis competency in first year dentistry students	Does not include psychomotor skills, only abstract available
Gonzalez-Cabezas et al ⁴³	Association between dental student-developed exam questions and learning at higher cognitive levels	Does not include psychomotor skills.
Öcek et al ⁴⁴	Development of a rational antibiotic usage course for dentists	Does not include psychomotor skills. Course development
Asadoorian & Batty ⁴⁵	An evidence-based model of effective self-assessment for directing professional learning	Does not include psychomotor skills, description of methodology
Clark et al ⁴⁶	'On Track' - An educational resource to support dental SHO training	Evaluation of an educational resource for dental Senior Health Officer. Broad educational resource beyond psychomotor skills
Davenport et al ⁴⁷	Learning throughout life: can a progress file help?	Feedback on a lifelong learning tool, does not include psychomotor skills
Kournetas et al ⁴⁸	Assessing the reliability of a digital preparation assistant system used in dental education	Does not include students
Haj-Ali & Feil ⁴⁹	Rater reliability: short-and long-term effects of calibration training	Does not include students
Sharaf et al ⁵⁰	Intra-and inter-examiner variability in evaluating preclinical pediatric dentistry operative procedures	Does not include students

McAndrew & Pierre ⁵¹	Using multiple measures to evaluate a dental faculty development program	Does not include students
Renne et al ⁵²	E4D compare software: an alternative to faculty grading in dental education	Does not include students
AlHumaid et al ⁵³	Agreement in Scoring Preclinical Dental Procedures: Impact on Grades and Instructor-Related Determinants	Does not include students
Garland & Newell ⁵⁴	Dental hygiene faculty calibration in the evaluation of calculus detection	Does not involve dental students
Schmitt et al ⁵⁵	Study on the Interrater Reliability of an OSPE (Objective Structured Practical Examination) – Subject to the Evaluation Mode in the Phantom Course of Operative Dentistry	Does not involve dental students
Jenkins et al ⁵⁶	Evaluating undergraduate preclinical operative skill; use of a glance and grade marking system	Does not include students
Fitzgerald et al ⁵⁷	A longitudinal study of self-assessment accuracy	Does not include dental students
Gordon M ⁵⁸	A review of the validity and accuracy of self-assessments in health professions training	Does not include dental students
Thammasitboon et al ⁵⁹	Problem-based learning at the Harvard school of dental medicine: Self-assessment of performance in postdoctoral training	Mostly clinical
Pileggi, Roberta Glickman, Gerald N. ⁶⁰	A cost-effective simulation curriculum for preclinical endodontics	Description of new teaching method
McAndrew et al ⁶¹	Characteristics of effective simulation (preclinical) teachers as	Not an assessment intervention

	identified by dental students: A qualitative study	
Mays & Branch-Mays ⁶²	A Systematic Review of the Use of Self-Assessment in Preclinical and Clinical Dental Education	Not an intervention but literature review
de Azevedo et al ⁶³	Comparative Effectiveness of Dental Anatomy Carving Pedagogy: A Systematic Review	Not an intervention. Lit rev
Postma & White ⁶⁴	Developing clinical reasoning in the classroom - analysis of the 4 C/ID-model	Not an intervention
Matheos et al ⁶⁵	Assessment of knowledge and competencies related to implant dentistry in undergraduate and postgraduate university education	This is not an intervention but investigates and describes assessments methodologies for implantology
Firmstone et al ⁶⁶	Systematic review of the effectiveness of continuing dental professional development on learning, behavior, or patient outcomes	This is not an intervention but literature review on CPD effectiveness
Hauser & Bowen ⁶⁷	Primer on Preclinical Instruction and Evaluation.pdf	This not an intervention but a review of the literature
Nance, Elizabeth T Lanning, Sharon K Gunsolley, John C ⁶⁸	Dental anatomy carving computer-assisted instruction program: an assessment of student performance and perceptions	Compares traditional delivery vs computer assisted
Dantas, Alessandra K. Shinagawa, Adriana Deboni, Maria Cristina Z. ⁶⁹	Assessment of Preclinical Learning on Oral Surgery Using Three Instructional Strategies	Evaluation of three teaching methods rather than assessment feedback intervention
Boushell et al ⁷⁰	Learn-A-Prep II as a predictor of psychomotor performance in a restorative dentistry course	Investigate the potential of Learn-A prep to early diagnose students' psychomotor skills
Polyzois et al ⁷¹	Can evaluation of a dental	Investigate the effectiveness

	procedure at the outset of learning predict later performance at the preclinical level? A pilot study	of conventional pre-clinical training
Gadbury-Amyot, Cynthia C Purk, John H Williams, Brian Joseph Van Ness, Christopher J. ⁷²	Using tablet technology and instructional videos to enhance preclinical dental laboratory learning	Investigate the impact of tablet technology with accompanying instructional videos on teaching and learning outcomes in a preclinical dental laboratory setting
Bedi et al ⁷³	Agreement of gradin using pictorial grading criteria	Did not involve psychomotor skills
Morrow, Jay A Pulido, M Teresa Smith, P Bradford McDaniel, Thomas F Willcox, Austin B ⁷⁴	Effective use of e-grading in the dental simulation clinic	Describe the development and implementation of a grading software
Barrero et al ⁷⁵	Dental Students' Perceived Preparedness to Treat Patients in Clinic After a Fixed Prosthodontics Course: Survey Results of a Case Study	Not assessment feedback involved
Schuster, G. M. Hunt, R. J. Haering, H. J. ⁷⁶	Effect of a Pilot Preclinical Incentive Program on Dental Students' Performance on a Clinical Competency Exam	Intervention is not on assessment feedback
Shugars, D. A. May, K. N. Vann, W. F. ⁷⁷	Comprehensive evaluation in a preclinical restorative dentistry technique course	Description of evaluation system
Wiegman, JE van de Poel, FCM Purdell-Lewis, D ⁷⁸	The value of an assessment system in a preclinical amalgam exercise	Description of evaluation system (to see amalgam adaptation)
Abrams, RG Kelley, ML ⁷⁹	Student self-evaluation in a pediatric-operative technique course	Description of evaluation system
Edwards, W. S. Morse, P. K. Mitchell, R. J. ⁸⁰	A practical evaluation system for preclinical restorative dentistry	Description of evaluation system

Forehand, Lena S Vann, WF Shugars, DA ⁸¹	Student self-evaluation in preclinical restorative dentistry	Description of evaluation system does not compare groups
Cho, George C Chee, Winston WL Tan, Derek T ⁸²	Dental Students' Ability to Evaluate Themselves in Fixed Prosthodontics"	Description
San Diego, JP Newton, T Quinn, BFA Cox, MJ Woolford, MJ ⁸³	Levels of agreement between student and staff assessments of clinical skills in performing cavity preparation in artificial teeth	Description
Denehy, GE Fuller, JL ⁸⁴	Student peer evaluation: an adjunct to preclinical laboratory evaluation	Description
Brehm, TW ⁸⁵	Peer evaluation of fixed partial dentures in a preclinical course	Description
Satterthwaite, J. D. Grey, N. J. A. ⁸⁶	Peer-group assessment of pre- clinical operative skills in restorative dentistry and comparison with experienced assessors	Description
Olson, PC Comet-Epstein, S ⁸⁷	Increasing objectivity in evaluation for a preclinical technique course	Description
Karl, M. Graef, F. Wichmann, M. Beck, N. ⁸⁸	Evaluation of tooth preparations - A comparative study between faculty members and pre-clinical students	Description
Cohen, S. Silverstri, A ⁸⁹	Evaluation of describing and grading preclinical technical exercises	Description
Bazan, MT Seale, NS ⁹⁰	A technique for immediate evaluation of preclinical exercises	Description
Nick, Doyle et al ⁹¹	The ability of dental students and faculty to estimate the total occlusal convergence of prepared teeth	Description
Foley, J. I. Richardson, G. L. Drummie, J. ⁹²	Agreement Among Dental Students, Peer Assessors, and Tutor in Assessing Students' Competence in Preclinical Skills	Description

Lee, C. et al ⁹³	The Relationship Between Dental Students' Assessment Ability and Preclinical and Academic Performance in Operative Dentistry	Description
Puryer & O'Sullivan ⁹⁴	An introduction to standard setting methods in dentistry	Curriculum development not an intervention
Marshall et al ⁹⁵	Evidence-based dentistry: assessment to document progression to proficiency	Curriculum development not an intervention
Field et al ⁹⁶	The Graduating European Dentist: A New Undergraduate Curriculum Framework INTRODUCTION	Not an assessment intervention
Gerhard-Szep et al ⁹⁷	Assessment formats in dental medicine: An overview	Not an intervention but review of assessments in dentistry
Feil ⁹⁸	Designing preclinical instruction for psychomotor skills (I)-- theoretical foundations of motor skill performance and their applications to dental education	There is not an intervention
Chambers and Gissberger ⁹⁹	Toward a competency analysis of operative dentistry technique skills	There is not an intervention
Manogue et al ¹⁰⁰	2.1 Evolving methods of assessment	There is not an intervention
Knight ¹⁰¹	Toward faculty calibration	There are not students involved
Kavadella et al ¹⁰²	Recommendations for the development of e-modules for the continuing professional development of European dentists Recommendations for the development of e-modules for the continuing professional development of European dentists	This is not an intervention
Kramer et al ¹⁰³	Dental student assessment toolbox	This is not an intervention but a description of multiple

Moore & Durham ¹⁰⁴	Invited commentary: issues with assessing competence in undergraduate dental education	assessment methods This is not an intervention but a discussion on assessments in dentistry
Redwood et al ¹⁰⁵	The missing link: self-assessment and continuing professional development	This is not an intervention but a document of SA in CPD context
Council of European Dentist ¹⁰⁶	Competences required for the practice of dentistry in the European Union	This is not an intervention but a document on competencies
Licari et al ¹⁰⁷	Designing evaluation forms to facilitate student learning	This is not an intervention but methodology description
Albino et al ¹⁰⁸	Assessing dental students' competence: best practice recommendations in the performance assessment literature and investigation of current practices in predoctoral dental education	This not an intervention on assessment feedback but an investigation on past and current assessment methodologies.
Feil & Gatti ¹⁰⁹	Validation of a motor skills performance theory with applications for dental education	Validation of theory rather than intervention
Rhienmora, Phattanapon et al ¹¹⁰	Intelligent dental training simulator with objective skill assessment and feedback	Technology feedback
Kateeb, E. T. et al ¹¹¹	Utilising an innovative digital software to grade pre-clinical crown preparation exercise	Technology feedback
Quinn, Frank et al ¹¹²	A study comparing the effectiveness of conventional training and virtual reality simulation in the skills acquisition of junior dental students	Technology feedback
Callan, Richard S. et al ¹¹³	Effect of employing different typodonts when using E4D Compare for dental student	Technology feedback

	assessment	
Taylor, C. L. Grey, N. J. A. Satterthwaite, J. D. ¹¹⁴	A comparison of grades awarded by peer assessment, faculty and a digital scanning device in a pre-clinical operative skills course	Technology feedback
Callan, Richard S. et al ¹¹⁵	Inter- and intra-rater reliability using different software versions of E4D compare in dental education	Technology feedback
Callan, Richard S. et al ¹¹⁶	The validity of using E4D compare's “% comparison” to assess crown preparations in preclinical dental education	Technology feedback
Kikuchi, Hirono Ikeda, Masaomi Araki, Koji ¹¹⁷	Evaluation of a virtual reality simulation system for porcelain fused to metal crown preparation at Tokyo medical and dental University	Technology feedback
Kwon, S. R. et al ¹¹⁸	Dental anatomy grading: comparison between conventional visual and a novel digital assessment	Technology feedback
Mays, K. A. Levine, E. ¹¹⁹	Dental Students' Self-Assessment of Operative Preparations Using CAD/CAM: A Preliminary Analysis	Technology feedback
Tiu, Janine et al ¹²⁰	Effectiveness of Crown Preparation Assessment Software As an Educational Tool in Simulation Clinic: A Pilot Study	Technology feedback
Zou, Huiru et al ¹²¹	A cavity preparation evaluation system in the skill assessment of dental students	Technology feedback
Esser, C. et al ¹²²	A comparison of the visual and technical assessment of preparations made by dental students	Technology feedback

Koo, Samuel et al ¹²³	An initial assessment of haptics in preclinical operative dentistry training	Technology feedback
Yekta, Sareh et al ¹²⁴	Evaluation of new injection and cavity preparation model in local anesthesia teaching	Technology feedback
Cardoso, J. A. et al ¹²⁵	Reducing subjectivity in the evaluation of pre-clinical dental preparations for fixed prosthodontics using the Kavo PrepAssistant®	Technology feedback
Mays, Keith et al ¹²⁶	Utilizing CAD/CAM to measure total occlusal convergence of preclinical dental students' crown preparations	Technology feedback
McPherson, Karen R. et al ¹²⁷	Utilizing self-assessment software to evaluate student wax-ups in dental morphology	Technology feedback
Callan et al ¹²⁸	Effectiveness and feasibility of utilizing E4D technology as a teaching tool in a preclinical dental education environment	Technology feedback
Gottlieb, Riki et al ¹²⁹	Predicting performance in technical preclinical dental courses using advanced simulation	Technology feedback
Wiegman, Jan. ⁷⁸	The value of an assessment system in a preclinical amalgam exercise (it uses a stereoscope 20X)	Technology feedback
Arnetz, G Dornhofer, R ¹³⁰	PREPAssistant: a system for evaluating tooth preparations	Technology feedback
Begazo, CC Feilzer, AJ ¹³¹	Effectiveness of preparation guidelines for an all-ceramic	Technology feedback

	restorative system	
Jasinevicius, T et al ¹³²	An evaluation of two dental simulation systems: virtual reality versus contemporary non-computer-assisted	Technology feedback
Wierinck, Els et al ¹³³	Effect of augmented visual feedback from a virtual reality simulation system on manual dexterity training	Technology feedback
Wierinck, Els et al ¹³⁴	Effect of reducing frequency of augmented feedback on manual dexterity training and its retention	Technology feedback
Wierinck, Els et al ¹³⁵	Effect of tutorial input in addition to augmented feedback on manual dexterity training and its retention	Technology feedback
Sharaf et al ⁵⁰	Intra-and inter-examiner variability in evaluating preclinical paediatric dentistry operative procedures	Technology feedback
Sadid-Zadeh et al ¹³⁶	Effectiveness of virtual assessment	Technology feedback
Kunkel et al ¹³⁷	The present study compared the subjective grading of student tooth preparations by experienced, well-calibrated faculty with objective digital grading of the same preparations by means of the PrepCheck software.	Technology feedback
Mettes et al ¹³⁸	Routine oral examination:	Clinical setting

	Clinical vignettes, a promising tool for continuing professional development?	
O'Sullivan et al ¹³⁹	The introduction of a new assessment system in restorative dentistry: The undergraduate and patient experience	Clinical setting
Ali, K et al ¹⁴⁰	Use of peer assessment in tooth extraction competency	Clinical setting
Bousdras, V et al ¹⁴¹	Assessment of surgical skills in implant dentistry	Clinical setting
Woolley, S. et al ¹⁴²	A pilot study of the use and perceived utility of a scale to assess clinical dental teaching within a UK dental school restorative department	Clinical setting
Chandrasekaran, S. et al ¹⁴³	Dental Students' Reflections on Quality of Periodontal Care in Dental School Clinics	Clinical setting
Karaharju-Suvanto, T. et al ¹⁴⁴	Gender differences in self-assessed clinical competence-a survey of young dentists in Finland	Clinical setting
Redford, R. et al ¹⁴⁵	Student perceptions of exodontia competency assessment in a UK dental school	Clinical setting

Sanderson, T ¹⁴⁶	Evaluating Student Self-Assessment through Video-Recorded Patient Simulations	Clinical setting
Redwood, C. et al ¹⁴⁷	Improving clinical assessment: Evaluating students' ability to identify and apply clinical criteria	Clinical setting
Gonzalez, B et al ¹⁴⁸	Implementation of a Peer-Evaluation Process	Clinical setting
Kirkup, M. et al ¹⁴⁹	Development and implementation of an electronic clinical formative assessment: Dental faculty and student perspectives	Clinical setting
Gordon, N ¹⁵⁰	Learning experiences of oral hygiene students in the clinical environment	Clinical setting
Lin, C et al ¹⁵¹	Correlation of rater training and reliability in performance assessment: Experience in a school of dentistry	Clinical setting
Prescott-Clements, L ¹⁵²	Measuring the development of insight by dental health professionals in training using workplace-based assessment	Clinical setting

Sennhenn-Kirchner, S. ¹⁵³	The effect of repeated testing vs repeated practice on skills learning in undergraduate dental education	Clinical setting
Macluskey, M. and Hanson, C. ¹⁵⁴	The retention of suturing skills in dental undergraduates	Clinical setting
Macluskey, M. ¹⁵⁵	Development of a structured clinical operative test (SCOT) in the assessment of practical ability in the oral surgery undergraduate curriculum	Clinical setting
Moore, W. and Bauchmoyer, S. ¹⁵⁶	Student and Faculty Perceptions of Dental Hygiene Clinical Evaluations	Clinical setting
Walton, J.et al ¹⁵⁷	Student ePortfolios to develop reflective skills and demonstrate competency development: Evaluation of a curriculum pilot project	Clinical setting
Weinlander, G. ¹⁵⁸	Period end clinical evaluation	Clinical setting
Abdulhadi, L. and Mohammed, H. ¹⁵⁹	Six years' results of partially edentulous patients' treatment in academic institute	Clinical setting
Behere, R ¹⁶⁰	Introduction of mini-CEX in undergraduate dental education in India	Clinical setting

Bookhan, V. et al ¹⁶¹	Criteria referenced student self-assessment in restorative dentistry	Clinical setting
Bowers, J and Wilson, J ¹⁶²	Graduates' perceptions of self-assessment training in clinical dental hygiene education	Clinical setting
Bridges, S. et al ¹⁶³	Clinical Assessment Judgements and 'Connoisseurship': Surfacing Curriculum-Wide Standards Through Transdisciplinary Dialogue	Clinical setting
Bush, H et al ¹⁶⁴	Failing to fail: clinicians' experience of assessing underperforming dental students	Clinical setting
Cairns, A et al ¹⁶⁵	Evaluation of a pilot peer observation of teaching scheme for chair-side tutors at Glasgow University Dental School	Clinical setting
Chadwick, R ¹⁶⁶	Maximizing the clinical exposure of dental students to conservative dentistry: design and evaluation of a novel system	Clinical setting
Dahllöf, G. et al ¹⁶⁷	A logbook for continuous self-assessment during 1 year in paediatric dentistry	Clinical setting

Devlin, H ¹⁶⁸	Students' perception of the prognosis for a single-surface amalgam restoration	Clinical setting
Evans, A et al ¹⁶⁹	The influence of self-deception and impression management upon self-assessment in oral surgery	Clinical setting
Evans, A et al ¹⁷⁰	Reliability of peer and self-assessment scores compared with trainers' scores following third molar surgery	Clinical setting
Evans, A et al ¹⁷¹	Assessment of surgeon competency to remove mandibular third molar teeth	Clinical setting
Hunter, H et al ¹⁷²	Deriving clinical performance standards	Clinical setting
Ihm, J and Seo, D. ¹⁷³	Does reflective learning with feedback improve dental students' self-perceived competence in clinical preparedness?	Clinical setting
Mackenzie, R ¹⁷⁴	Factors essential to evaluation of clinical performance	Clinical setting
Mackenzie, R et al ¹⁷⁵	Analysis of disagreement in the evaluation of clinical products	Clinical setting

Manogue et al ¹⁷⁶	Clinical assessment of dental students: Values and practices of teachers in restorative dentistry	Clinical setting
Metz, M et al ¹⁷⁷	Student Self-Assessment of Operative Dentistry Experiences: A Time-Dependent Exercise in Self-Directed Learning	Clinical setting
Napankangas, R. et al ¹⁷⁸	Can the results of the OSCE predict the results of clinical assessment in dental education?	Clinical setting
Navickis M et al ¹⁷⁹	Examining clinical assessment practices in US dental hygiene programs	Clinical setting
Scott, B et al ¹⁸⁰	An investigation into the use of a structured clinical operative test for the assessment of a clinical skill	Clinical setting
Van der Sanden, W et al ¹⁸¹	Effectiveness of clinical practice guideline implementation on lower third molar management in improving clinical decision-making: a randomized controlled trial.	Clinical setting
Vernazza, C et al ¹⁸²	Introduction of an e-portfolio in clinical dentistry: Staff and student views	Clinical setting

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Figure 1: Systematic review flow chart of the literature search and selection process

Figure 2: Risk of bias for Randomised Controlled Trials

Study ID	Experimental	Comparator	Outcome	Weight	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Feil and Reed ²⁴	Intervention	No intervention	Students skills	1	+	+	+	+	+	+
Shah et al ²⁵	Intervention	No intervention	Students skills	1	+	+	+	+	?	+

Low risk
Some concerns
High risk