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Teaching strategies and assessment of psychomotor skills in dental education: Scoping Review

Estrategias didácticas de enseñanza y evaluación de habilidades psicomotrices en la educación de odontología: Scoping Review

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Summary:

Introduction: Dentistry requires high manual dexterity to perform precise procedures in the oral cavity. These skills, known as psychomotor skills, integrate cognitive and motor abilities that allow the student to adapt and interact effectively with their environment. Since these skills are mainly developed through constant practice, rigorous training is crucial before clinical contact with patients. Simulation, as an educational tool, has gained special relevance due to its ability to replicate real clinical conditions, favoring the development of technical and cognitive skills. **Methods**: An electronic search was performed in the PubMed, Scopus and Web of Science databases, following the PRISMA-ScR and JBI protocols and using the Rayyan AI software. **Results**: The main teaching strategies include low-fidelity simulation, screen simulators and virtual resources. Regarding assessment, these strategies are divided into diagnosis, training and self-assessment. The most notable features of these tools include benefits for students in terms of developing motor skills, confidence, and self-criticism, as well as reducing the teaching load during assessment, improving educational planning, and providing useful feedback. **Conclusions:** The strategies analyzed are effective for developing and/or measuring multiple skills or knowledge simultaneously. However, the lack of information on their influence on meaningful learning limits their implementation. Future studies are needed to delve deeper into their effectiveness, detailing application protocols to facilitate comparison of strategies and optimize their use in dental training.

Keywords: Motor Skills, Aptitude Test, Manual Dexterity Test, Psychomotor Exercise, Simulation Training, Dental Education

Abstract:

Introducción: La carrera de odontología requiere una alta destreza manual para ejecutar procedimientos precisos en la cavidad oral. Estas habilidades, conocidas como psicomotricidad, integran capacidades cognitivas y motoras que permiten al estudiante adaptarse e interactuar eficazmente con su entorno. Dado que estas habilidades se desarrollan principalmente mediante la práctica constante, es crucial contar con un entrenamiento riguroso antes del contacto clínico con pacientes. La simulación, como herramienta educativa, ha cobrado especial relevancia por su capacidad para replicar condiciones clínicas reales, favoreciendo el desarrollo de habilidades técnicas y cognitivas. **Métodos**: Se realizó una búsqueda electrónica en las bases de datos PubMed, Scopus y Web of Science, siguiendo el protocolo PRISMA-ScR, JBI y utilizando el software I.A. Rayyan. **Resultados**: Las principales estrategias de enseñanza incluyen simulación de baja

fidelidad, simuladores de pantalla y recursos virtuales. En cuanto a la evaluación, estas estrategias se dividen en diagnóstico, formación y autoevaluación. Las características más destacadas de estas herramientas incluyen los beneficios para los estudiantes en términos de desarrollo de habilidades motoras, seguridad y autocrítica, así como la reducción de la carga docente en la evaluación, mejorando la planificación educativa y proporcionando retroalimentación útil. **Conclusiones:** Las estrategias analizadas son efectivas para desarrollar y/o medir múltiples habilidades o conocimientos simultáneamente. No obstante, la falta de información sobre su influencia en el aprendizaje significativo limita su implementación. Se hace necesario que futuros estudios profundicen en su efectividad, detallando protocolos de aplicación para facilitar la comparación de las estrategias y optimizar su uso en la formación odontológica.

Palabras clave: Habilidades Motoras, Prueba de Aptitud, Prueba de Destreza Manual, Ejercicio Psicomotor, Entrenamiento de Simulación, Educación de Odontología

1. Introduction

Dental education requires manual dexterity to perform precise procedures in the oral cavity (1). These skills, known as psychomotor skills, integrate cognitive and motor abilities that enable adaptation and interaction with the environment (2-7). In the dental context, psychomotor skills are developed through constant practice, making rigorous training essential before clinical care. In Latin America, dental schools have adopted a competency-based teaching-learning approach, which not only recognizes the distinct learning styles and individual needs of students but also integrates clear definitions of expected competencies, taxation matrices linked to the graduate profile, and a detailed curriculum mapping. This approach allows for teaching and assessing specific learning milestones using authentic methods that reflect the future professional's work activities (8-9). This approach includes a variety of teaching strategies, from initial teaching to assessment (10). Among these, simulation stands out for its ability to replicate the clinical field, allowing students to practice procedures and improve their quality (11-12).

To more accurately describe educational simulation tools, Guillaume Alinier proposed a typology based on technological complexity in 2007, structured into six levels. This classification ranges from written simulations (level 0), through three-dimensional models and computerized simulators (levels 1 and 2), to standardized patients, intermediate-fidelity simulators, and high-fidelity mannequins (levels 3 to 5, respectively). This typology allows for a clearer comparison and selection of the most appropriate resources for each stage of clinical learning, taking into account both their level of sophistication and their specific pedagogical objectives (13). Maran and Glavin (2003) proposed a six-level typology, ranging from written clinical cases (level 0) to high-fidelity simulators with advanced physiological responses (level 5) (14). These levels include: basic three-dimensional models, digital simulators, standardized patients, intermediate-fidelity mannequins, and highly interactive simulators. This classification allows resources to be selected according to the learning objectives and the desired level of competence, promoting progressive training adapted to the dental environment (14).

On the other hand, assessment is essential to verify the effectiveness of teaching strategies, both at the conceptual and procedural and attitudinal levels (14-15). It can be applied for diagnostic, formative, or summative purposes (16-19) and classified as hetero-assessment, co-assessment, and self-assessment depending on the assessing agent (16). These tools not only measure performance but also provide valuable information to guide the learning process. Despite advances in teaching methods, current literature tends to analyze individual strategies linked to specific skills, without integrating or classifying the available resources in a structured way. This fragmentation limits the understanding of the didactic landscape and hinders its practical implementation. The lack of a guide that relates strategies with psychomotor objectives and assessment methods represents a significant gap in dental education.

In response to this need, we propose a literature review to map and characterize the teaching strategies used in psychomotor skills development in dentistry. This review seeks to answer the question: What teaching strategies are used in dental education for the development of psychomotor skills? Through the analysis of available evidence, we aim to identify, organize, and

compare these strategies, with the goal of contributing to the continuous improvement of teaching and assessment processes in the dental field.

2. Methods

This study used the Joanna Briggs Institute (JBI) protocol for the development of the materials and methods section (20). In addition, the PRISMA-ScR protocol was adopted for the selection of articles (21).

Eligibility Criteria

Articles in Spanish or English published within the last 10 years (2013–2023) were included, considering that this period reflects a significant boom in research related to the development of manual skills in dental training, virtual reality, motor testing, and teaching strategies, in addition to being related to curricular changes in Latin America, especially in Chile. This temporal delimitation is based on the rapid technological and methodological evolution in the field of dentistry, which ensures that the selected studies are aligned with current practices and the most recent trends. Studies related to psychomotor skills in childhood, older adults, psychiatric illnesses, neuromuscular injuries, pharmacological effects, or sports were excluded.

Information Sources and Search Strategy

A systematic literature search was conducted on December 16, 2023, in the PubMed, Scopus, and Web of Science databases. For articles of interest without full access, an electronic search was conducted through the Dental Library of the University of Valparaíso.

Search Strategy

The search strategy was based on Medical Subject Headings (MeSH) terms and the following search keys were designed:

Database	Search Terms
PubMed	(1) "Motor skills" AND "teaching strategies" NOT "Child" (2) "psychomotor performance" AND "adult" AND "dentistry" NOT "children"
Scopus	(3) "Motor skills" AND "dental school" OR "dental students" (4) "Motor skills" OR "psychomotor ability" OR "psychomotor skills" OR "fine motor skills" OR "dental skills" OR "manual abilities" OR "manual dexterity" OR "manual skill" AND "aptitude tests" OR "dexterity test" OR "admission test" OR "manual dexterity test" AND "dental education" OR "dentistry education" OR "dental schools" OR "school dentistry" OR "dental student"
Web of Science	(4) "Motor skills" OR "psychomotor ability" OR "psychomotor skills" OR "fine motor skills" OR "dental skills" OR "manual abilities" OR "manual dexterity" OR "manual skill" AND "aptitude tests" OR "dexterity test" OR "admission test" OR "manual dexterity test" AND "dental education" OR "dentistry education" OR "dental schools" OR "school dentistry" OR "dental student"

Selection of Articles

Two reviewers (MJ and ER) independently assessed all titles and abstracts from the selected databases using the Rayyan platform in blinded mode. Full-text articles were obtained after applying the inclusion and exclusion criteria. Disagreements regarding the final inclusion of articles were resolved by consensus with a third reviewer (GO). The collected data were recorded in a specially designed Excel spreadsheet. General information about the studies was compiled, including title, author, year of publication, and country of origin. In addition, study characteristics (design, objective, sample size) and characteristics of the strategies analyzed (method, tool, modality, purpose, tool description, application protocol, limitations, and main findings) were

recorded, following the guidelines established by the JBI protocol. The review included two themes: teaching methods and assessment methods. Teaching methods were defined as those capable of promoting the learning and improvement of dental students' psychomotor skills, such as clinical simulation, the use of dental mannequins, and virtual reality. Assessment methods were defined as those capable of measuring psychomotor performance, including manual dexterity tests, practical examinations, and competency-based assessments.

3. Results

A total of 799 articles were found in the databases used. A total of 769 articles were included for reading their titles and abstracts after eliminating 30 duplicate articles. A total of 756 articles were excluded for not meeting the objectives, leaving a total of 13 potential articles for inclusion in the review, which were subjected to a complete reading by two reviewers (MJ, ER). In addition, five studies of interest from EBSCO were added through manual searching . Finally , 18 articles were included. The articles eliminated in this process did not meet the proposed objectives. This is detailed in the PRISMA ScR diagram (18) (Figure 1).

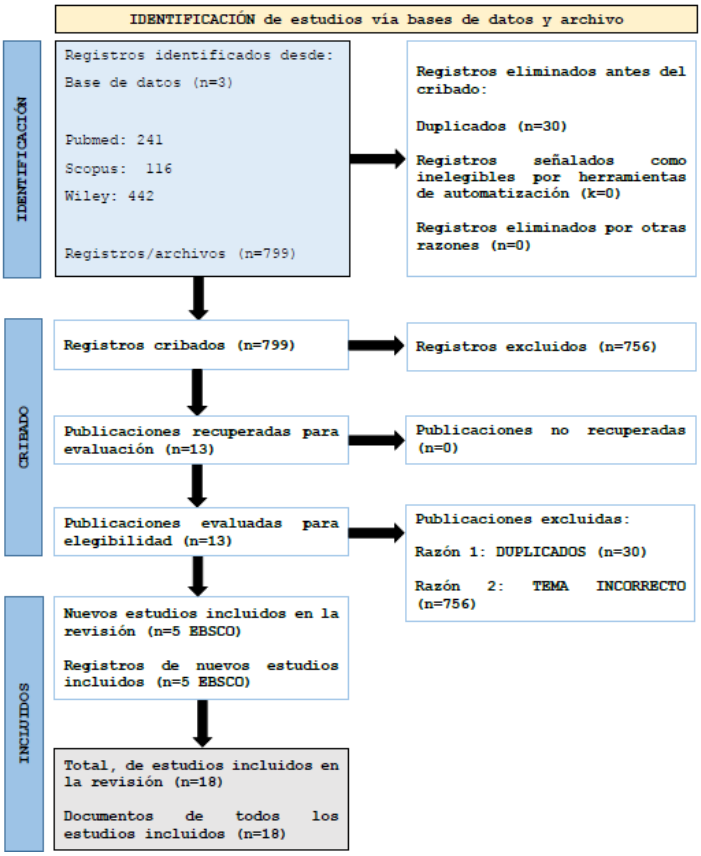

Figure 1. Flowchart of item selection.

General characteristics

A total of 18 articles published between 2013 and 2023 were included. The geographic distribution was diverse, with a predominance of research conducted in the United States (n=5), Canada (n=3), and Israel (n=2). All studies were written in English and included participants of both sexes. Regarding the methodological design, seven articles were cohort studies, five were experimental studies in the educational field, five were pilot studies, and one was cross-sectional. Regarding sample size, significant variability was observed, ranging from a minimum of 26 participants (Matthisson et al., 2022) to a maximum of 854 (Novack et al., 2020), with a median of 72 participants per study (Table 1).

Table 1. Country, design, sample size and follow-up of the studies.

Author	Country	Study design	Sample size	Follow-up period
	Australia	Experimental Study	75	6 months
El-Kishawi et al. (2023)	USA	Pilot	96	Not reported
Imbery et al. (2023)	Swiss	Pilot	26	3 months
Matthisson et al. (2022)	Israel	Pilot	42	Not applicable
Shely et al. (2021)	Thailand	Pilot	30	8 weeks
Su Yin et al. (2021)	United Kingdom	Cohort	72	Not reported
Al-Saud et al. (2020)	Canada	Cohort	854	1 year
Novack et al. (2020)	Mexico	Cohort	44	4 months
Reyes-Acuca et al. (2020)	Saudi Arabia	Experimental Study	30	Not applicable
Alzahrani et al. (2019)	Israel	Cohort	106	6 months
Lugassy et al. (2019)	USA	Experimental Study	47	12 weeks
McClure et al. (2019)	Canada	Cohort	123	Not reported
Cleghorn et al. (2018)	Germany	Cohort	129	Not applicable
Schwibbe et al. (2016)	Sweden	Cohort	286	2 years
Christersson et al. (2015)	USA	Experimental Study	26	Not applicable
Gadbury-Amyot et al. (2014)	USA	Experimental Study	81	1 semester
Maresca et al. (2014)	Canada	Pilot	36	8 weeks
Kilistoff et al. (2013)	USA	Cross	39	Not applicable

Main findings:

The included studies analyzed innovative strategies for teaching in dentistry, which were grouped into two main categories : teaching strategies and assessment strategies (Table 2).

Table 2. Type of strategy, tools and concepts evaluated

Author (Year)	E. didactics	Tool	Concepts evaluated
El-Kishawi et al. (2023)	Teaching	Videos	Acquisition of manual skills, retention of knowledge
Imbery et al. (2023)	Assessment	Wax carving	Fine motor skills, quality of restorations
Matthisson et al. (2022)	Assessment	Intraoral Scanning	Technical competence, procedural efficiency
Shely et al. (2021)	Teaching	PhantHome	Visuomotor coordination, execution time
Su Yin et al. (2021)	Teaching and Assessment	Haptic Simulator	Operative precision, immediate feedback
Al-Saud et al. (2020)	Assessment	Haptic	Psychomotor skills, learning curve

		Simulator	
Novack et al. (2020)	Assessment	PAT, MDT	Comprehensive clinical competence
Reyes-Acuca (2020)	Teaching	DASM	Effectiveness in preclinical training
Alzahrani et al. (2019)	Teaching	SODAR	Acquisition of basic surgical skills
Lugassy et al. (2019)	Teaching	PhantHome	Transfer of skills to the clinical setting
McClure et al. (2019)	Teaching	Jumpstart Mirror Trainer	Bilateral coordination, efficiency in movements
Cleghorn et al. (2018)	Assessment	MDT	Manual skill predictive of clinical success
Schwibbe et al. (2016)	Assessment	HAM-MAN Test	Visual-spatial and manual skills
C. Christersson et al. (2015)	Assessment	Raven and Folding Dies	Cognitive and manual skills
Gadbury-Amyot et al. (2014)	Teaching	Videos	Retention of theoretical and practical knowledge
Maresca et al. (2014)	Teaching	Sakai Platform	Effectiveness of self-directed learning
Kilistoff et al. (2013)	Assessment	Wax carving	Progression in manual skills
Urbankova et al. (2013)	Teaching and Assessment	Haptic Simulator	Efficiency in cavity preparations

Teaching Strategies

A total of nine studies evaluated teaching methods in dentistry using simulation, virtual environments, and digital platforms. The tools used included the use of instructional videos (23-25), haptic simulators (12, 26), digital platforms such as Sakai (27), and specific devices such as PhantHome (11, 28), DASM (Dental Anaesthesia Simulation Model) (29), Jumpstart Mirror Trainer (24), and SODAR (Simulator for Oral Dental Anatomy and Restoration) (30) (Table 2). These studies reported significant improvements in variables such as manual accuracy, reduced learning time, student satisfaction, transfer to the clinical setting, and reduction of errors in basic procedures. In general, strategies based on simulation and digital resources showed greater effectiveness compared to traditional methods (23, 24, 26-30).

Evaluation Strategies

At least eight studies addressed diagnostic or formative assessment methods, using tools such as wax carving (24, 31), intraoral scanning (32, 33), haptic simulators (12, 26, 34), MDT (35), PAT (36), HAM-MAN (27), and cognitive matrices (25). Associations were found between performance on these assessments and clinical performance, as well as significant differences based on students' level of experience, gender, or cognitive abilities. These strategies allowed for the identification of progress in psychomotor, technical, visuospatial, and cognitive skills, and also predicted clinical success in some areas such as endodontics.

Combined Teaching and Assessment Strategies

Two studies simultaneously integrated teaching and assessment components using haptic simulators with immediate feedback. These interventions resulted in significant improvements in operating skills and a reduction in technical errors compared to conventional methods.

4. Discussion

The reviewed studies show a growing use of innovative strategies in dental education, focusing on simulation and psychomotor assessment. These technologies have demonstrated a positive impact on basic skill acquisition; however, significant limitations persist regarding their

applicability in complex procedures, their predictive capacity for clinical performance, and their long-term impact (1-14, 24-29, 31-32, 34-42).

Haptic simulators (Al-Saud et al., 2020; Su Yin et al., 2021; Urbankova et al., 2013) have been shown to be particularly effective for initial skill development, with 83% of studies reporting improvements in operative accuracy, especially in cavity preparations (32, 34, 39). However, their use in advanced procedures has been poorly evaluated, with only one study applying them to endodontics (34). However, benefits have also been documented in clinical techniques such as local anesthesia, particularly in improving perceptions of learning, student self-confidence, and procedural performance (43–47). This gap is relevant given that 67% of studies (12/18) focused exclusively on basic skills, without sufficiently addressing how these technologies can contribute to the development of advanced clinical competencies (1-9, 26-27, 35).

Regarding assessment tools, results were contradictory. The PAT showed a moderate correlation with preclinical skills (r=0.42), but its ability to predict performance in real-life clinical settings was limited (37, 48-49). This has also been observed with other sections of the Dental Admission Test, whose correlation with clinical performance in integrated assessments has been inconclusive (50). In contrast, some studies have proposed incorporating direct practical tests, such as Wire Bending, which have shown a greater ability to predict performance in preclinical courses (51). However, there are preparation strategies specifically designed to improve performance on this test, such as those developed in cognitive training platforms (52). Similar findings were observed with wax carving, which, while allowing monitoring of fine motor progress, failed to demonstrate robust predictive validity for clinical performance (31, 36, 53). This questions the usefulness of these tools as sole assessment instruments and suggests the need to combine them with other more specific and contextualized measures. An example of these alternatives is the use of intraoral scanning, which has demonstrated sensitivity in detecting motor improvements in longitudinal studies (33), as well as haptic simulators with objective feedback, which offer a more standardized evaluation of clinical performance (54) and whose acceptance by students and teachers has been largely positive (55), supported by studies that validate their reliability as an objective tool for measuring manual skills (56). Furthermore, it has been shown that these simulators allow differentiating between students with and without previous clinical experience, demonstrating their usefulness as a formative and discriminative assessment tool (57).

A recurring methodological problem was the limited assessment of long-term impact. Only two studies (11%) conducted follow-up periods exceeding six months (25, 28), making it impossible to determine whether improvements are sustained or transferred to real-world clinical practice. This limitation is exacerbated by the fact that 78% of the studies (14/18) used small samples (median = 72 participants) in highly controlled settings (1-9, 11-14, 24). Furthermore, the heterogeneity in methodological designs and measurement instruments (7 different approaches) hampers direct comparison and synthesis of results.

From an educational perspective, data suggest that these technologies are most effective when integrated into a blended learning model, improving both student performance and satisfaction in real-life clinical settings (58). Furthermore, techniques such as the flipped classroom and spaced learning have also shown positive results in the acquisition of theoretical and practical knowledge (59).

Tools such as PhantHome (24) and DASM (29) were particularly useful in reducing learning times (30–40%) and improving visuomotor coordination ($p<0.05$ in 4/5 studies), but their effectiveness was greater when complemented with supervised clinical practice. This integrated approach seems especially promising to reduce the gap between simulated training and performance with real patients, since recent evidence supports the effectiveness of combining active exploration with audiovisual instruction in teaching complex clinical procedures (60).

It is necessary to move towards longitudinal studies that evaluate the sustained impact of these strategies, as well as their effectiveness in the development of complex clinical competencies. Likewise, it will be essential to build more flexible curricular frameworks that articulate simulation with supervised practical teaching, following pedagogical models that consider the stages of

learning as a basis for the selection of methods and resources (61). This will involve not only providing technological resources to institutions, but also transforming teaching roles and gradually redesigning curricula to ensure a progressive transition from basic skills to advanced clinical competencies, following curricular proposals focused on the progressive integration of theory and clinical practice (62), in line with the principles of meaningful learning proposed by Bruner, which highlight the importance of a gradual and cumulative structure of knowledge (63).

5. Conclusions

- The results highlight that methods such as haptic simulators, digital platforms, and standardized assessment tools promote the acquisition of basic skills, with 83% of studies reporting improvements in operative accuracy and error reduction. However, significant limitations persist, particularly in the application of these technologies to complex procedures and in their ability to predict actual clinical performance, as evidenced by the moderate correlation (r=0.42) of the PAT with preclinical skills.
- The limited information on long-term impact—only 11% of the studies included follow-up periods longer than six months—and the methodological heterogeneity identified make it difficult to generalize the results. This underscores the need for longitudinal studies that assess not only skill retention but also their effective transfer to clinical practice, using standardized parameters that include technical performance, patient safety, and procedural efficiency.
- An integrated approach is recommended that combines innovative technologies with traditional methods, adapting curricula to ensure a smooth transition from basic skills to advanced competencies. Future research should address current limitations through more robust methodological designs, with representative samples and extended follow-up, to fully determine the potential of these strategies in dental training. Only then can we ensure that these tools do not simply develop isolated skills, but contribute to meaningful and lasting learning in future professionals.

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Table 3. Consolidated table of studies

Author (Year)	Country	Study design	Sample size	Follow-up period	Type of teaching strategy	Method analyzed	Tool analyzed	Concepts evaluated	Key results
El-Kishawi et al. (2023)	Australia	Experimental Education Study	75	6 months	Teaching	Virtual	Videos	Acquisition of manual skills, retention of knowledge	Significant improvement in accuracy vs. control group ($p<0.05$)
Imbery et al. (2023)	USA	Pilot	96	Not reported	Assessment	Diagnostic Evaluation	Wax carving	Fine motor skills, quality of restorations	Correlation between manual dexterity and clinical performance ($r=0.62$)
Matthisson et al. (2022)	Swiss	Pilot	26	3 months	Assessment	Formative Assessment	Intraoral Scanning	Technical competence, procedural efficiency	30% reduction in technical errors vs. traditional evaluation ($p<0.01$)
Shely et al. (2021)	Israel	Pilot	42	Not applicable	Teaching	Simulation	PhantHome	Visuomotor coordination, execution time	Learning time reduced by 25% with simulator ($p<0.05$)
Su Yin et al. (2021)	Thailand	Pilot	30	8 weeks	Teaching and Assessment	Simulation, Formative Assessment	Haptic Simulator	Operative precision, immediate feedback	40% improvement in skills vs. non-simulator group ($p<0.01$)
Al-Saud et al. (2020)	United Kingdom	Cohort	72	Not reported	Assessment	Diagnostic Evaluation	Haptic Simulator	Psychomotor skills, learning curve	Significant differences between novices and experts ($p<0.001$)

Novack et al. (2020)	Canada	Cohort	854	1 year	Assessment	Diagnostic Evaluation	PAT, MDT	Comprehensive clinical competence	Association between PAT results and academic success (OR=2.1; 95% CI:1.4-3.0)
Reyes-Acuca et al. (2020)	Mexico	Cohort	44	4 months	Teaching	Simulation	DASM	Effectiveness in preclinical training	50% reduction in errors in basic procedures ($p<0.05$)
Alzahrani et al. (2019)	Saudi Arabia	Experimental Education Study	30	Not applicable	Teaching	Virtual	SODAR	Acquisition of basic surgical skills	35% improvement in accuracy vs. traditional methods ($p<0.05$)
Lugassy et al. (2019)	Israel	Cohort	106	6 months	Teaching	Simulation	PhantHome	Transfer of skills to the clinical setting	Correlation between simulator performance and clinical evaluation ($r=0.71$)
McClure et al. (2019)	USA	Experimental Education Study	47	12 weeks	Teaching	Simulation	Jumpstart Mirror Trainer	Bilateral coordination, efficiency in movements	20% reduction in procedure time vs. control group ($p<0.05$)
Cleghorn et al. (2018)	Canada	Cohort	123	Not reported	Assessment	Diagnostic Evaluation	MDT	Manual skill predictive of clinical success	MDT scores associated with endodontic performance ($\beta=0.45$; $p<0.01$)
Schwibbe et al. (2016)	Germany	Cohort	129	Not applicable	Assessment	Diagnostic Evaluation	HAM-MAN Test	Visual-spatial and manual skills	Significant gender differences in

									manual dexterity ($p<0.05$)
C. Christersson et al. (2015)	Sweden	Cohort	286	2 years	Assessment	Self-assessment	Raven and Folding Dies	Cognitive and manual skills	Moderate correlation between cognitive abilities and clinical skills ($r=0.52$; $p<0.001$)
Gadbury-Amyot et al. (2014)	USA	Experimental Education Study	26	Not applicable	Teaching	Virtual	Videos	Retention of theoretical and practical knowledge	15% improvement in theoretical exams vs. traditional method ($p<0.05$)
Maresca et al. (2014)	USA	Experimental Education Study	81	1 semester	Teaching	Virtual	Sakai Platform	Effectiveness of self-directed learning	Greater student satisfaction vs. face-to-face method ($p<0.01$)
Kilistoff et al. (2013)	Canada	Pilot	36	8 weeks	Assessment	Formative Assessment	Wax carving	Progression in manual skills	Progressive improvement in carving scores ($p<0.05$ per week)
Urbankova et al. (2013)	USA	Cross	39	Not applicable	Teaching and Assessment	Simulation, Formative Assessment	Haptic Simulator	Efficiency in cavity preparations	35% reduction in surgical errors vs. control group ($p<0.01$)

Source: Prepared by the authors.