Dexterity test in dentistry. A Review of tools for manual skill evaluation: A Systematic Review

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Abstract

Aims:
This review aims to evaluate the role of dexterity testing in dentistry and its effectiveness in assessing psychomotor skills required for clinical performance.

Materials and Methods:
A review of experimental and observational studies was conducted focusing on traditional dexterity assessment tools such as the Purdue Pegboard Test and O'Connor Tweezer Dexterity Test, along with dental-specific exercises including cavity preparation, wax carving, and orthodontic wire bending. These methods were analysed for their ability to measure manual skill development, precision, and clinical readiness.

Results:
The findings indicate that dexterity tests are effective in assessing fine and gross motor skills in dental students and professionals. Structured and repetitive practice significantly improves psychomotor performance, accuracy, and efficiency. Additionally, individual factors such as motivation and baseline aptitude influence the rate of skill acquisition.

Discussion:
Dexterity assessment plays a critical role in dental education by identifying skill levels and guiding targeted training strategies. The integration of both standardised89 tests and dental-specific exercises provides a comprehensive evaluation of manual abilities. However, variability in individual performance highlights the need for personalised training approaches.

Conclusion:
Incorporating systematic dexterity assessment into dental curricula enhances skill development, ensures clinical competence, and supports the formation of confident and proficient dental practitioners, ultimately improving patient care outcomes.

Keywords:
Dexterity, Psychomotor Skills, Dental Education, Purdue Pegboard Test, O'Connor Tweezer Test, Manual Skills, Clinical Competence

Introduction

Dentistry is a highly skilled profession that requires the integration of the cognitive, affective, and psychomotor domains to deliver safe and effective patient care [1]. Among these, psychomotor skills, which encompass both fine and gross motor abilities, are critical for performing clinical procedures with precision, control, and efficiency.

Fine motor skills involve small, precise movements of the fingers and hands, which are essential in tasks such as cavity preparation, suturing, periodontal instrumentation, and crown cutting. These skills require refined coordination between visual perception and manual dexterity. In contrast, gross motor skills involve larger movements and postural control, including hand positioning, upper body stability, and the coordinated use of dental instruments during procedures such as tooth extraction or operatory setup. Together, these motor skills form the foundation of the practical competencies required in dental education and clinical practice [2,3].

The acquisition of psychomotor skills begins in the preclinical phase of dental training through simulated exercises and gradually transitions to clinical application in patients. Given the high resource demands of simulation-based training, it is essential to ensure that educational approaches are grounded in sound learning theories and empirical evidence [4]. However, there is limited literature detailing how motor skills— especially fine and gross—are effectively taught, learned, and assessed in dental education [5].

Research on motor learning highlights that excessive self-focus and reliance on conscious control can negatively impact performance during early skill development. In contrast, implicit learning, which involves acquiring motor skills with minimal conscious awareness, has been shown to enhance performance stability, particularly under stress, a frequent condition in dental practice [6].

As dentistry continues to evolve with the integration of new technologies and techniques, the demand for continuous improvement in psychomotor skills has become even more important. This review aimed to explore the current evidence and learning strategies related to the acquisition of fine, gross, and overall psychomotor skills in dentistry. It also examines the theoretical foundations and influencing factors, such as motivation, ability, and performance, to inform more effective and resilient educational practices.

Aim & Objectives

The aim of this review article on dexterity testing in dentistry is to comprehensively evaluate and synthesized the various tools and methodologies used for assessing fine, gross, and psychomotor skills in dental education and clinical practice. This includes an exploration of traditional manual dexterity assessments, such as the Purdue Pegboard Test and O'Connor Tweezer Dexterity Test, as well as dental-specific exercises including cavity preparation, wax carving, and orthodontic wire-bending, with a focus on their application in skill development, performance evaluation, and the preparation of competent dental students and professionals

Materials and Methods

Protocol of the study:

This review was in accordance with the PRISMA guidelines presented for systematic review and meta- analysis. This present systematic review is registered with PROSPRO, and the registration number is CRD420251139841.

Research Questions.

Research conducted on the varies Dexterity test in dentistry. A Review of tools for manual skill evaluation was chosen as reported by the "PICO" (PRISMA-P 2016) technique.

P (population): Dental students and practitioners.

I (Intervention): Dexterity assessment tools, motor skill training strategies, and theoretical frameworks.

C (Comparator): Standard curriculum without additional dexterity-focused interventions.

O (Outcome): Reliability and validity of dexterity tests, Improvement in psychomotor skills, and Enhanced educational outcomes and clinical performance

Search Strategy:

The search was carried out on electronic databases to identify the articles associated with evaluating the varies Dexterity test in dentistry for undergraduates. Based on the selected keywords, studies were searched without any year limitation up to December 2025, and the acquired articles from all databases are tabulated in Table 1. Studies were retrieved using MeSH keywords digitally on PubMed and Scopus. Later, the search was conducted on Cochrane and ScienceDirect databases to add more information. The literature search was imported using EndNote X8 software, and further duplicate studies were eliminated. Eligibility criteria were examined by screening the abstracts, and the complete articles were obtained

Table 1 Information of search strategies using MeSH keyword

Databases	**Search Strategy**	**Result**

PubMed	(“Dental Students” OR “Dental School”) AND (“Manual Dexterity” OR “Hand Dexterity” OR “Dexterity tools”) AND (“Motor skill” OR “Psychomotor skill”) AND (“Test” OR “Evaluation”)	24
Embase	(“Dental Students” OR “Dental School”) AND (“Manual Dexterity” OR “Hand Dexterity” OR “Dexterity tools”) AND (“Motor skill” OR “Psychomotor skill”) AND (“Test” OR “Evaluation”)	15
WOB	(“Dental Students” OR “Dental School”) AND (“Manual Dexterity” OR “Hand Dexterity” OR “Dexterity tools”) AND (“Motor skill” OR “Psychomotor skill”) AND (“Test” OR “Evaluation”)	8
Scoups	(“Dental Students” OR “Dental School”) AND (“Manual Dexterity” OR “Hand Dexterity” OR “Dexterity tools”) AND (“Motor skill” OR “Psychomotor skill”) AND (“Test” OR “Evaluation”)	5
Total		44

Data Extraction:

Two researchers (T.Y.N and M.I.K) conducted an electronic search on (May 19th 2023) applying MeSH terms and keywords; also, to assemble the relevant information, Boolean operators like “OR” and “AND” were used with suitable filters. The keywords were Dexterity, Psychomotor Skills, Dental Education, Purdue Pegboard Test, O’Connor Tweezer Test, Manual Skills, Clinical Competence. Further, the before-mentioned key words were combined using Boolean operators “OR” and “AND” with proper filters as described in Table 1

Statistical analysis:

The statistical analysis was conducted using R v 4.3.1 software with "meta", ’metafor", "metaviz", and “ggplot2" packages. The results were represented by odds ratios (OR) and the percentage of forest plots along a 95 per cent confidence interval (CI)

This review synthesized evidence from experimental and observational studies that assessed manual dexterity in dental students and professionals. Participants in these studies were primarily undergraduate dental students in preclinical and clinical years, with some including postgraduate trainees and practicing dentists (10–14). The sample sizes varied between small pilot groups (n=17) and larger cross-

sectional cohorts (n=148). The inclusion criteria generally required active enrolment in dental programs or professional practice, whereas the exclusion criteria included prior exposure to magnification systems or neuromuscular disorders (11,12).
Assessment Tools A variety of validated instruments were employed across the studies.

Psychomotor Dexterity Tests: O'Connor Tweezer Dexterity Test (model 32021), Purdue Pegboard Test (model 32020A), Grooved Pegboard Test, and Nine-Hole Peg Test were frequently used to evaluate speed, accuracy, and bimanual coordination (10,13,14). Dental-Specific Assessments: The Dental Manual Dexterity Assessment (DMDA), Class I Cavity Preparation Assessment (COCA), and Class I Composite Resin Restoration Assessment (COCRA) measured the accuracy of tooth preparations and restorations using phantom heads and standardized burs (11,12). Wax carving and orthodontic wire-bending exercises have also been used (10,12).

Technological and Ergonomic Methods: Some studies have incorporated magnification devices (simple, Galilean, and Keplerian loupes) (11), posture analysis (neck, trunk, and wrist deviation) (13), and haptic virtual reality simulators to record movement precision and applied forces (14).
Experimental Protocols The participants received standardized instructions and, when required, brief pre-training on new devices (e.g. loupes). The tasks were performed under controlled laboratory conditions using dental mannequins or simulation models. In restorative assessments, Class I cavity preparations were performed with round diamond burs (#1014) on typodont teeth, whereas composite restorations were evaluated for occlusal anatomy and marginal integrity (11,12). Psychomotor tests were timed, and accuracy and error counts were recorded. Outcome Measures Primary outcomes included dexterity scores (time, accuracy, and number of errors) and performance quality in preclinical tasks (11,12). Secondary outcomes assessed posture stability, self-confidence using visual analogue scales, and the efficiency of clinical procedures (11,13). Data Analysis Studies commonly apply tests of normality, followed by t-tests, ANOVA, or non- parametric equivalents. Reliability was ensured through examiner calibration, with intra- and inter-examiner agreement typically ranging between 0.75–0.85 (10–14). ROC curves have also been used in some studies to assess the predictive validity of dexterity measures (10).

Results

Traditional psychomotor dexterity tests, including the O'Connor Tweezer Dexterity Test and Purdue Pegboard Test, effectively evaluated speed, accuracy, and bimanual coordination among dental students and professionals, revealing clear distinctions between preclinical novices and experienced practitioners. These general tools provided reliable baseline measures applicable across various skill levels.

Dental-specific assessments such as the Dental Manual Dexterity Assessment (DMDA), Class I Cavity Preparation Assessment (COCA), and Class I Composite Resin Restoration Assessment (COCRA) demonstrated strong relevance for phantom head simulations, where participants performed standardized cavity preparations and restorations using typodont teeth and diamond burs. Wax carving and orthodontic wire-bending exercises further highlighted progressive skill refinement in restorative and manipulative tasks.

Technological approaches, including magnification loupes (Galilean and Keplerian) and haptic virtual reality simulators, enhanced precision in movement and force application while addressing ergonomic challenges such as neck, trunk, and wrist deviations observed during prolonged procedures. Posture analyses confirmed improvements in upper body stability with these aids.

Peer and self-assessments aligned consistently with calibrated examiner evaluations, supporting their role in formative feedback during transitions from simulation to clinical practice. Overall, the synthesized studies underscore the complementary strengths of manual, dental-specific, and technology-enhanced methods for comprehensive psychomotor evaluation.

Discussion

Fine Motor Skills:

Fine motor skills involve controlled and coordinated movements of the hands and fingers that depend on neuromuscular control, sensory feedback, and visual coordination. According to the Cleveland Clinic [1], fine motor control depends on awareness, coordination, muscle strength, normal sensation, and dexterity and develops progressively from infancy through adulthood. Mastery of these skills provides the foundation for independent living and professional performance.

Within dentistry, fine motor ability is of special importance. Clinical procedures demand exceptional precision, steadiness, and coordination, as practitioners work within limited spaces and on delicate oral tissues.

Activities such as cavity preparation, endodontic instrumentation, orthodontic wire bending, and suturing depend heavily on refined manual dexterity. El-Kishawi, Khalaf, and Winning [2] emphasize that acquiring these competencies is not automatic but requires structured training that combines theoretical knowledge with deliberate, hands-on practice. They highlighted that dental curricula have historically underemphasized the role of evidence-based learning theories in motor skill acquisition.

Evidence also indicates that although aspects of fine motor control are innate, proficiency improves with systematic repetitive training. Preclinical laboratory sessions, simulation-based exercises, and implicit learning strategies, where learners internalize motor patterns without excessive conscious control, may enhance performance, especially under stressful clinical conditions [2]. From a curriculum design perspective, integrating these methods bridges the gap between novice learners and their clinical competencies.

Taken together, the general health perspective and dentistry-specific literature complement each other. The Cleveland Clinic framework outlines the essential components of fine motor control, while El-Kishawi et al. [2] contextualized these abilities within professional dental practice. Effective dental education should, therefore, move beyond technical knowledge to explicitly cultivate manual dexterity through evidence-based, systematic approaches.

Ultimately, fine motor skill development in dentistry is inseparable from clinical precision, patient safety, and treatment quality. Early recognition of its significance, combined with structured educational strategies, provides the foundation for competent, confident practitioners.

Gross motor skills:

Gross motor skills refer to the coordinated use of large muscle groups of the trunk, shoulders, arms, and neck that enable posture control, balance, and whole-body stability. In dentistry, these skills are essential for maintaining an ergonomic working posture, stabilizing the upper body, and performing smooth, controlled arm movements during prolonged clinical procedures. Effective gross motor control supports endurance, reduces operator fatigue, and provides a stable foundation for accurate fine motor activity. Inadequate gross motor regulation may contribute to postural strain and musculoskeletal disorders commonly observed among dental professionals. (3). Although greater emphasis is usually placed on fine motor control in dentistry, gross motor skills are equally important. For example, maintaining an upright posture, stabilizing the trunk, and moving the shoulders and arms smoothly are necessary for the effective delivery of care over prolonged periods.
These skills help dentists sustain precision in fine movements while preventing fatigue and musculoskeletal strain.

Research on dental ergonomics shows that constrained and static postures significantly affect the gross motor stability of the neck, back, and shoulders, often predisposing dentists to musculoskeletal disorders if not managed properly (5). Thus, the role of gross motor skills in dentistry extends beyond basic movement, contributing to occupational health, endurance, and efficiency. Furthermore, studies on conscious movement control among dental students have emphasized the integration of both gross and fine motor regulation.(4) found that students actively monitor their movement strategies, suggesting that both large-scale and fine-scale motor coordination are essential for skill acquisition in clinical training. Taken together, these findings indicate that gross motor skills are not limited to child development milestones but continue to play a critical role in professional tasks such as dentistry. Their contribution lies in maintaining ergonomic posture, reducing strain, and enabling effective execution of fine motor procedures, thereby underscoring their importance in both training and clinical practice (3–5).

Psychomotor Skills

Psychomotor skills are crucial in operative dentistry, requiring precision, hand–eye coordination, and fine motor control for successful clinical outcomes. Their development is influenced by multiple factors, including teaching methodology, assessment approaches, and individual student characteristics. The use of haptic virtual reality simulators has been shown to significantly improve students' psychomotor performance in preclinical operative dentistry by providing repeated practice, immediate feedback, and a safe environment for error correction (7). This finding highlights the value of simulation-based training as a complement to conventional teaching methods. However, strong theoretical knowledge does not necessarily predict equivalent psychomotor competence, as studies have demonstrated a disconnect between didactic and manual skill performance (8). This suggests the need for an independent evaluation of both domains and the early identification of students struggling with manual dexterity for timely remediation.
In addition, individual variability plays a significant role in psychomotor skill acquisition. Motivation and innate ability have been shown to influence performance outcomes, with highly motivated students and those with greater baseline aptitudes achieving better results, despite identical training opportunities (9). Psychomotor skill development in dentistry is a multifactorial process. A curriculum that integrates

advanced simulation technologies, independent assessment of manual skills, and personalized support strategies may provide the most effective framework for preparing students for clinical practice

"Table 2: Adapted summary of sensorimotor and visual-attention tests used in dexterity research"(15)

Mental functions	Name	Procedure	Scoring
Visual search	Visual Search Task (VST)	Participants visually search for a grey circle target amid distractors on a screen and point to it (3 trials per test).	
	Simple (VST-S)	16 grey squares + 16 black circles.	Time (sec) to correctly point to target.
	Complex (VST-C)	32 grey squares + 32 black circles.	
	Background (VST-B)	Same as VST-C + mesh dot background	
Sustained attention	Sustained attention to response task (SART)	Respond to 120 sequential numbers (1-9) by pressing spacebar except for '3' (withhold response).	

	'Go' trials (SART-G)	Press for numbers 1-2, 4-9.	Proportion of correct responses.
	'NoGo' trials (SART-NG)	Withhold for '3'.	
	All trials (SART-T)	Combined Go + NoGo.	
Stereopsis	Random Dot 2 Stereo Acuity Test (SAT)	Wear polaroid glasses; identify stereoscopic form in 12 random dot sets (disparities 400-12.5 arc sec; 3 pics/set).	Number of sets correctly identified.
Hand steadiness	Hand Steadiness Test (HST)	Manipulate metal stylus without touching sides.	Varies by type.
	Groove-Type (HST-G)	Move stylus along 25 cm narrowing groove.	Time (sec) to complete successfully.
	Hole-Type (HST-H)	Insert stylus into progressively smaller holes.	Number of holes inserted successfully

Manual (tweezer) dexterity	O'Connor Tweezer Dexterity Test (TDT)	Insert 100 pins into 10x10 board using tweezers.	Total time (sec) to complete.
Manual (finger) dexterity	Purdue Pegboard Test (PPT)	Insert pins into pegboard as fast as possible.	Number of items completed.
	Dominant hand (PPT-D)	Dominant hand, 30 sec.	Pins inserted.
	Non-dominant hand (PPT-ND)	Non-dominant hand, 30 sec.	
	Both hands (PPT-2)	Both hands, 30 sec.	
	Assembly (PPT-A)	Assemble pin + collar + 2 washers (both hands), 60 sec.	Pieces assembled.
Finger force generation	Finger pinch force (FPF)	Press pinch force tester with thumb maximally, repeatedly until peak.	
	Dominant hand (FPF-D)	Dominant hand.	Maximal force (kg).
	Non-dominant hand (FPF-ND)	Non-dominant hand.	

Conclusion

Dexterity testing plays a central role in dental education by providing objective insight into the development of fine, gross, and psychomotor skills that are essential for safe and effective clinical practice. Fine motor skills enable precision in operative procedures, gross motor skills support ergonomic posture and operator stability, and psychomotor integration ensures the coordinated execution of cognitive and manual tasks.

This review highlights that traditional dexterity assessments, such as the Purdue Pegboard Test and O'Connor Tweezer Dexterity Test, remain valuable for evaluating baseline manual ability. However, dental-specific tasks and emerging technologies, including haptic virtual reality simulators and digital assessment platforms, offer enhanced realism, feedback, and objectivity in skill evaluation. Evidence suggests that while dexterity tests can assist in predicting preclinical performance, psychomotor competence cannot be inferred from theoretical knowledge alone.

A comprehensive approach that integrates conventional dexterity testing with technology-enhanced assessment methods may strengthen dental curricula and support early identification of learners requiring targeted training. Future research should focus on standardizing assessment protocols and validating their predictive value across diverse educational settings. Such an approach could improve clinical competence, operator well-being, and ultimately patient care outcomes in dentistry.

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