REVIEW ARTICLE

Dexterity and Motor Skill Development in Dentistry: A Narrative Review

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Abstract

The ability to work with accuracy and perfect harmony is essential for safe, effective dental care. Every clinician relies on established motor skills to manage activities effectively and minimize strain, whether they are performing everyday care or complex treatments. Over time, developments in digital simulations and motor learning theory have altered how these crucial skills are taught in dental colleges. This review aims to study the development of motor skills in dentistry, emphasizing training methodologies and assessment techniques for recording progress. It also takes into account the increasing influence of digital tools, such as virtual reality and interactive simulations, for enhancing experiential learning. The reviewed previous studies were in PubMed, Web of Science, Scopus, and Google Scholar. The selected literature searched for terms such as motor learning, psychomotor skills, dexterity evaluation, and dental education. That developing efficient motor abilities needs far more than practice. Both traditional and contemporary training methods, such as optimal theory and schema theory, provide insight into how motivation and feedback lead to improved skills. Dental students benefit from modern methods that use haptic instruments and virtual reality to practice fine movements and enhance precision. Motor skills are not only a component of dental education but are vital for competent clinical practice. Dental schools can help future professionals succeed by combining targeted instruction, practical experience, and acute use of technology.

Key words: Dental training, dexterity, motor learning, psychomotor skills, simulation, virtual reality

INTRODUCTION

Dentistry requires an enormous amount of clinical skill and involves large engagements of the cognitive, emotional, and psychomotor domains, as it is with other medical and paramedical courses.[1] Good clinical dental practice depends on acquiring advanced psychomotor skills and integrating them successfully.[2] Dental education compels the student to carry out high-precision steps that often involve irreversible manipulation of oral tissues; hence, this skill should be inculcated before getting involved with actual patients in a real clinical situation. Competence, therefore, has to be achieved by a student in the artificially controlled academic setup during the pre-clinical period for patient safety as well as treatment efficacy.[3] The ultimate objective of dental education is to ensure students are capable of providing safe, efficient, fully evidence-based oral healthcare independently.[4] This can be achieved through the gradual development of cognitive understanding, visual perception, and practical skills before moving on to treat patients directly. The manual skill becomes very important in filling the gap that exists between theoretical knowledge and its practical application clinically. Students join dental courses with varying backgrounds in psychomotor skills, which can influence their performance at the beginning while learning complicated tasks like cavity preparation, and tooth carving, among others related to fine-motor procedures. Manual

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dexterity is the ability to coordinate visual motor movements with accurate muscle activity, involving fine and gross motor skills, hand-eye coordination, spatial relations, and sensory feedback. It constitutes a multidimensional skill for which several standardized assessment tools exist: Among them are the Purdue Pegboard Test, Minnesota Manual Dexterity Test, Box and Block Test, O'Connor Finger Dexterity test, and Functional Dexterity Test.[5,6]

The tests focus on various aspects of dexterity and should be chosen concerning the particular clinical skills to be measured. Therefore, an early diagnosis of psychomotor problems would benefit dental education. A pre-or early-in pre-clinical training screening would let educators know if any students, individually or groups of students who need some guidance or specific training strategies have been found. Such skill-development interventions will help in achieving competency optimally besides minimizing earlier clinical performance difficulties. Also, as digital innovations and minimally invasive technologies keep shaping the future of dentistry, there is a growing need for more and more updates in psychomotor abilities to maintain standards in practice. Traditionally, motor abilities relevant to dentistry have been classified into fine, gross, and psychomotor components – contributing uniquely towards clinical performance. Dexterity comprises functional elements such as regulation of force, precision grip, power grip, grasping, manipulation and controlled movements of the hand and fingers.[7] The development of these abilities starts in childhood and gradually progresses through definite neurodevelopmental stages. Writing skill, cutting with scissors, stacking blocks and picking up small objects are the early indicators for normal manual dexterity development that has required a foundation built for further advanced clinical tasks.[8] Because dental procedures require substantial technical exactness, high levels of tactile sensitivity, bimanual coordination and manual steadiness, together with instrument handling proficiency, are required from the practitioners.[5] Daily clinical <PRIVATE_PERSON> activities strongly depend on psychomotor accuracy and hand-eye coordination-from scaling and polishing to operative, prosthodontic, and endodontic procedures. Thus, the manual dexterity component has been considered as the most imperative element for dental practice and professionalism competence. The simulation-based training component that includes typodont exercises, mannequin heads, phantom heads, virtual reality simulators, and pre-clinical laboratory of training is common for helping to acquire psychomotor skills in dental curricula around the world. Haptic technology, together with digital simulation, broadens further opportunities to achieve detailed feedback related to force application, angulation, and hand movement pattern. Evidence demonstrates that students provided with specific training in psychomotor skill areas perform better when dealing with real patients later because they make fewer procedural errors and are more confident. A dentist must maintain ergonomic postures, work in restricted fields, control indirect vision through mirrors, and operate micro-movements that avoid iatrogenic damage. It is during varied clinical problems supervised gradually that practice helps develop the complex integration of sensory input and motor output. The results of poor psycho-motor function are not only operator fatigue but also poor quality of treatment, increased working time, and possibility of errors. Individual differences in rates of psychomotor learning underscore the need for individualized educational strategies.[5,7] Some require extended training or adaptive instructional methods to achieve the same level of competence, while some can spring up rapidly to that level. Factors influencing dexterity baseline levels among students entering dental programs 11 may include prior handcraft activity experience, video gaming, musical instrument usage, visual-spatial intelligence, and even cultural aspects. In others, late interventions preceded by early screening prevent professional dissatisfaction or dropout later due to problems with mastery of manual skills. Other than pre-entry evaluation, objective structured clinical examinations and accompanying rubrics for skill assessment, together with digital performance analytics, are fast becoming essential elements in curriculum designs that will assist in tracking progress by educators toward eliminating learning deficits and appraising the degree of readiness for clinical engagement.[8,9] More technologically advanced clinically applied fields in dentistry raise the threshold of required competence in psychomotor skills. Furthermore, ergonomic training and the awareness of the musculoskeletal have recently gained much acclaim as factors that go into dexterity. Just as it may sound odd, chronic strain and bad posture do bear negative implications on manipulation ability and sustain a career for long years. Psychomotor skills as preparation for training are indicated in this respect of professional well-being in the long run and are, therefore, imperative. The confidence related to psychomotor skills is transmitted to manual work and hence gets reflected in professional behavior, communication, and perception of patients.[9-12] A dentist with confident hand movements inspires more trust from the patient so that treatment can be carried out comfortably. Errors in technique due to hesitation or application of excessive force lead to anxiety or pain responses; therefore, psychomotor competence reduces such unpleasant reactions. Manual dexterity is directly linked with clinical result, patient satisfaction level, and quality of care offered. Its multifactorial significance keeps manual dexterity at the core of interest in dental education research. Knowing how skills are gained, the effects of training methods, and good assessment plans help in getting the best learning results and creating skilled workers who can handle the tough needs of modern dental work.

METHODOLOGY

Mastery of motor skills is the basic foundation of dental education and directly determines the competency level and confidence buildup in the future clinician. It is an art that requires extreme accuracy, excellent fine caries control, and maneuvers implemented within a limited working area. Psychomotor development has always been a baseline factor despite placing considerable emphasis on cognitive knowledge in dental curricula towards determining success in clinical performance. Without well-coordinated motor skills, students will not be able to manipulate instruments accurately and ensure patient safety or carry out treatment procedures to an acceptable clinical standard. Therefore, the ways through which motor skills are developed, assessed, or improved in dental training have great core relevance to contemporary dental pedagogy. This narrative review will critically discuss the importance of motor skills in dental education with practical strategies, evidenced approaches supporting psychomotor, fine, and gross-motor skill development through preclinical to clinical progression of students [Figure 1]. Another objective of this paper is to describe the change that takes place in learners as they move from novices who need conscious control heavily to perform acts smoothly, effectively, and automatically like skilled experts. Much of the change is accounted for by deliberate practice and structured learning systematically based on theoretical principles governing motor learning that influence neurocognitive adaptation. This paper also intends to review a broad spectrum of psychomotor assessment instruments currently utilized in dental education and analyze their reliability, validity, and predictive value concerning actual patient care. A critical analysis provides an understanding that leads to the discovery of deficiencies in skills at an early stage; such a finding helps reduce student stress since targeted remedial programs can be instituted.

Other objectives comprise documentation on simulation-based training, haptic technologies, ergonomic interventions, and digital tracking systems that will contribute to measurable improvements in psychomotor performance. The review shall synthesize theoretical knowledge with practical teaching strategies to develop a guide for curriculum designers, educators, and policymakers who are looking forward to advocating reforms in strengthening the frameworks of competency-based dental education across all countries. This paper aims to provide an avenue through which it can be indicated that developing manual dexterity is not merely a passing academic exercise but a lifelong professional commitment. As more high-tech treatments are introduced into the field of dentistry – microsurgery, laser therapy, computer-aided design/computer-aided manufacturing restorative workflows – the greater the demand on the practitioner's psychomotor ability. In this respect, therefore, motor skill improvement continually predicts clinical excellence, patient satisfaction, and length of career. This narrative review used a systematic and comprehensive literature search strategy to guarantee the inclusion of high-quality, relevant research responding to or addressing psychomotor development in dentistry.

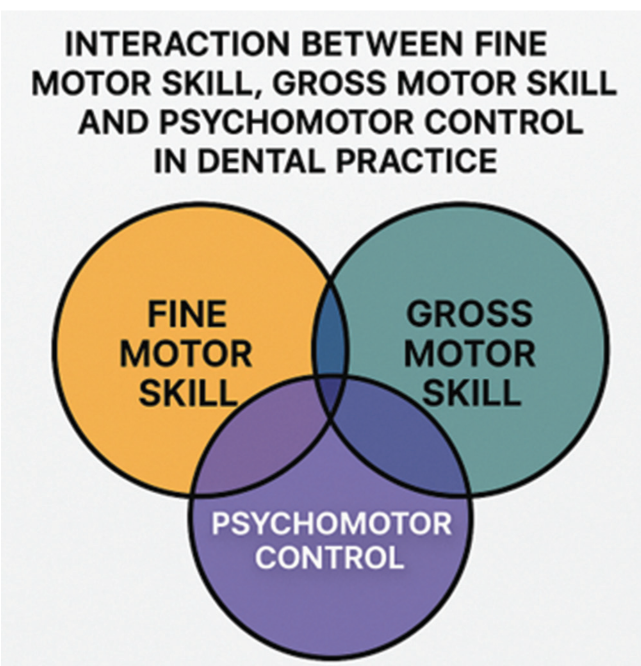

Figure 1: Components of motor skill in dentistry

The electronic search was structured on the following academic databases: PubMed, Scopus, Medline, and Google Scholar for studies published until October 2025. Other manual searches were carried out using ScienceDirect, SciELO, and National Library of Medicine sources so that no publication of relevance would be missed. The search query used a combination of MeSH terms and free-text keywords related to motor learning and dental education. The search words were dentistry, manual dexterity, fine motor skills, gross motor skills, psychomotor skills, dexterity tests, hand-eye coordination, dental students, skill acquisition, working memory, and learning theories. Boolean operators AND/OR were used to make the results more sensitive. All articles identified were screened by title and abstract at this stage Figure 2.

Those appearing relevant were taken into account for eligibility assessment against the predefined inclusion and exclusion criteria during a full-text review. Articles focusing on dental students', interns', or professional dentists' motor skill development were considered eligible; research that would discuss simulation-based learning, dexterity assessment techniques or theoretical explanations for skill mastery; and conceptual analyses of psychomotor integration in clinical practice. This review also excluded studies that involved the general non-dental population, *in vitro* laboratory analyses not relating to clinical skill performance, animal studies, and randomized controlled trials – those which focused on biological outcomes and did not discuss motor learning. Data extraction was conducted independently by summarizing authorship, year of publication, methodological design, skill assessment outcomes, learning models applied, and reported implications on dental education. The information extracted was thematically grouped to facilitate narrative synthesis with depth of analysis but without conducting statistical meta-evaluation as appropriate to the aim of a narrative review. The

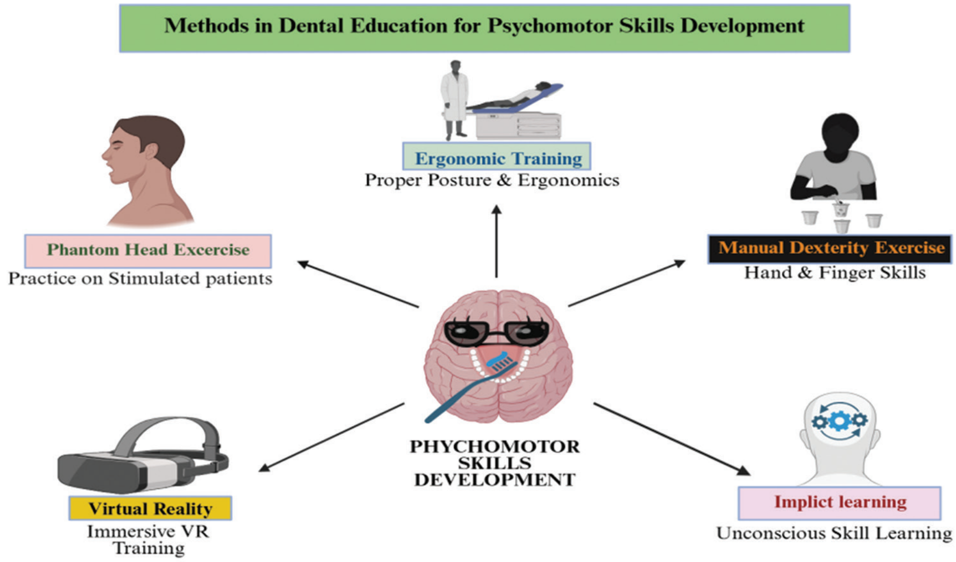

Figure 2: Methods in dental education for psychomotor skill development

cross-checking of reference lists from selected articles for any additional relevant literature ensured a stronger review process. Emphasis was placed during the synthesis phase on extracting conceptual patterns and weighing the impact that strategies have on motor skill development while bringing focus to under-researched areas. The goal at the heart of this methodological approach was an attempt to generate coherent and holistic comprehension of current evidence in psychomotor education for dentistry while simultaneously informing pedagogy improvement for the next generation of learners.

RESULTS

Reviewed literature revealed a strong interrelationship between the domain of motor skill and assessment methodologies applied in mapping the clinical competence of dental students. Fine motor skills are described as those movements that involve careful and coordinated use of hands and fingers 3. Tasks related to high visual–tactile accuracy include wax patterning, suturing, cavity preparation, and manipulation of orthodontic wires 1, 3. Gross motor skills describe larger muscle coordination with stable posture and controlled application of force; these are likened to tooth extraction, wherein ergonomic stability as well as proper instrument handling are compared and considered as important elements.[11-14] Deficiencies in gross motor control can negatively affect fine motor performance, leading to less accurate procedures with increased musculoskeletal strain during extended periods of clinical performance1. Psychomotor skill is thus an integrated concept that perceives the task as involving both fine and gross motor coordination with visual perception for successful execution in performing complex clinical activities. The Purdue Pegboard Test and O'Connor Tweezer Dexterity Test remain relevant as baseline evaluators of inherent motor capacities. Other dental-related assessment tools, which include less than more-advanced options such as virtual reality simulators and haptic feedback training, have proven objective and reliable in the consideration of factors related to technical accuracy, associated error frequency, spatial awareness, and the determination of skill improvement over time 1, 2. This information advocates for a multi-method technologically enhanced assessment strategy in the quest for improved validity, reliability, and predictive capacity of current assessments of motor skill competency in dental education 2.

DISCUSSION

Fine and gross motor skills in dentistry

Cognitive, sensory and neuromuscular processes interact continuously during the learning of motor skills.[11] In particular, mastering a fine motor skill – like endodontics – involves the integration and regulation of posture, motion, and muscle stimulation, which enables the performer to carry out a range of motor behaviors that are regulated by various task requirements.[12]

To gain fine motor skills, one must be able to control and integrate a variety of stimuli and reactions to complete the intended motor activity. How can we forecast, encourage, or explain how people pick up these skills? Numerous theories of learning have been established. To describe how motor skill acquisition happens and what motivates people to grow and adapt. To create learning activities that effectively promote the learning of their dental students, dental educators must have a solid understanding of pertinent learning theories.

Key theories such as schema theory, cognitive load theory, OPTIMAL theory of motor learning, the novice–expert continuum, and reinvestment theory together provide a clear understanding of how motor skills are acquired and improved [Figure 3]. These frameworks explain the basic principles and workflow involved in acquiring, practicing, and mastering psychomotor skills.

A. Schema theory[13] is one of the continuous processes that are updated during motor learning. Ability to remember and identify proprioceptive data from fingers and limbs. The reaction parameters, such as force and speed, are set based on the stored information
B. Cognitive load theory[14] considering that the cognitive system is constrained since working memory can only for a few seconds, save and process a small amount of data
C. The OPTIMAL theory[15] focuses on identifying the best teaching strategy to boost motivation and alignment of motor learning with the motor task's intended result
D. Reinvestment theory[16] considers the difference between a person's movement and self-consciousness characteristics in decision-making and movement processing
E. Novice-expert continuum and deliberate practice principles.[17] Expert motor performance development requires consistent, purposeful practice. It is enhanced by learning by trial and error under appropriate supervision.

Gross motor skills are those that depend on large muscles to perform bigger body movements, like ball play, climbing, running, jumping, and ambulation are all categorized as gross motor skills. According to neurodevelopmental theory, stability is overlaid on the mobility required for these gross motor skills. As a result, the child's neuromuscular and neurodevelopmental status determines both their capacity to do these activities and the caliber of their performance. The evaluation of a child's neuromuscular status is frequently seen as one aspect of their gross motor status. Therefore, assessing developmental milestones and observing the caliber of a child's movement patterns are both included in gross motor. As the kid completes a variety of motor tasks, stability and balance are assessed and monitored. These balance observations also apply to the child's vestibular processing, explaining how sensory signals guide motor behavior.[18]

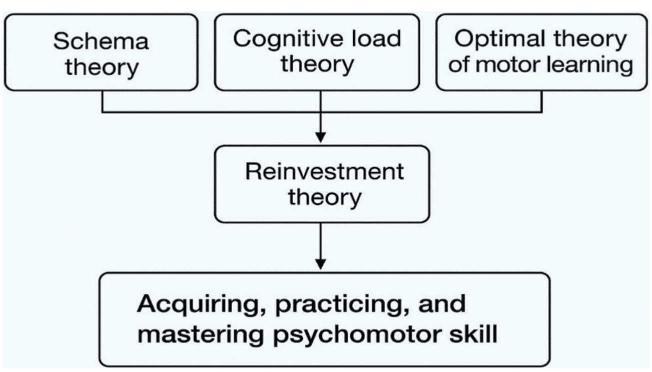

Figure 3: Theories to understand motor skills principles

Psychomotor skill training in dental education

Motor learning has been discussed for many years, with authors like McGeoch, Irion, and Adams tracing its development over time. In the early stages, research mainly focused on how people learned practical skills, how long these skills were retained, and how easily they could be transferred to different situations. The discussion of motor learning has spanned many years, with its development traced by authors such as McGeoch, Irion, and Adams. In the beginning, studies related chiefly to the manner by which people learned practical skills retained for how long these skills were retained, or how easily they could be transferred to other situations. Although it went out of fashion for a time, the subject regained its application interest because it applies in such diverse fields as health sciences, surgery, sports, and paramedical training.[19-21] Motor performance is what can be overtly observed on an individual like the end result of a task.

For instance, in dental education, when a student performs cavity preparation, and it is evaluated based on its final outcome – but does not indicate what the student has been doing all through the process, hence reducing even further the quality of feedback that can be provided by instructors. Motor learning, on the other hand, refers to how the individual gradually comprehends the steps involved in performing an action, makes adjustments, and improves performance as practice is repeated. According to Schmidt, this is accomplished by storing movement patterns or plans in memory that are further refined with experience over time.[21] Tedesco and colleagues emphasized that skill development should be based on research findings in dental education. However, most dental programs continue to mainly assess the final product while giving less consideration to the actual process of learning that takes place in developing psychomotor skills.[22]

The terms motor skills, technical skills, and manual skills are mostly used to denote what common parlance refers to as psychomotor skills. Psychomotor skills relate to some voluntary action coordinated by sensation-the signal travels from the brain along motor nerve pathways, which control muscles-thus differentiating between psychomotor ability and psychomotor skill. Psychomotor abilities are more fundamental and innate. Skills are acquired by training, and they can be adjusted eventually. Several abilities often participate in coordination to support one complex skill.[15-20]

These skills involve the coordination between sensory input and voluntary movements, where signals from the brain travel through motor nerve pathways to control muscles. It is important to differentiate between psychomotor ability and psychomotor skill. Psychomotor abilities are more basic and inherent, while skills are developed through training and can be improved over time. A single complex skill often relies on several underlying abilities working together. Psychomotor skill can therefore be described as the ability to perform, adjust, and refine precise and complex movements using continuous sensory feedback, especially from kinesthetic awareness of body movement.[23,24]

In dental education, several teaching methods are used to support psychomotor development:

1. Phantom head exercise: This exercise allows the dentist and dental students to work on the simulated patient (Dental Phantom Head). It provides a feel close to reality and more practical situations resembling actual treatment in various training areas such as restorative and prosthetic areas, endodontics, implantology, etc.[25]
2. Ergonomic training: To prevent work-related musculoskeletal disorders. It assures high productivity, avoidance of illness and injuries, and increased satisfaction among workers[25]
3. Manual dexterity exercise: It is the ability to effectively use your hands and fingers with precision. (Example) Squeeze play-dough (or) clay to strengthen hand muscles. Pick things up with a clothespin. Use tweezers to pick up small objects[24,25]
4. Implicit learning techniques: Implicit learning of motor skills includes learning skills without the accumulation of conscious verbal knowledge (e.g., rules). The aim is to limit the accumulation of movement-specific knowledge, decrease dependence on declarative knowledge structures[26]
5. Virtual reality: It refers to a non-conventional computer graphics system having a virtual sense of reality. Display technologies are developed in such a way that the human mind perceives them as an absolute reality, depending on the methods used, which bring humans to no other place[25,26]
6. Haptic simulation: It can significantly improve motor skill acquisition in preclinical dental training. It uses virtual reality and tactile feedback to allow students to practice and perfect dental procedures on virtual models[25,26]
7. These are the few methods that not only improve the psychomotor skills, but also enhance students' enhancement capability.

CONCLUSION

Assessment of manual dexterity continues to be heavily relied upon as an important input into the performance of dental students and its prediction in both practical and theoretical realms. Although tests such as the perceptual ability test and ham-man have found wide use, current literature underscores the fact that most extant assessments emphasize result-oriented performance at the expense of dynamic learning processes that inculcate enduring psychomotor competence. The development of psychomotor skills in dental practice involves a highly complicated activity requiring fine and gross motor skills, hand – eye coordination, spatial abilities, and cognitive processing. Apparent differences in baseline dexterity among entrants underscore the need for early diagnosis thereof, appropriate individualized remediation intervention, and vigilance to assure fairness in skill attainment and preparedness clinically. Among such emerging technologies are virtual reality simulators, haptic-feedback systems, and interactive digital platforms that can create repetitive sensitivity environments for trial-and-error learning with feedback to help further break down detailed tasks based on detected weaknesses. Most of the assessments available at present, irrespective of recent advancements, were not generated explicitly for dentistry. This fact highlights the dire need for validated dentistry-specific assessment tools that take into account ergonomics, implicit learning, and actual clinical demands. Technology-based training must merge with conventional instructional strategies to improve the development of skills and their assessment in an appropriate preclinical curriculum that moves the learner from conscious and deliberate performance to automatic expert performance necessary for safe and efficient clinical care. Future studies should focus on developing fine dentistry-specific comprehensive psychomotor assessment batteries that will include fine motor precision, gross motor stability, ergonomic awareness, and sensory integration in clinical decision-making. Such tools would better identify students, direct adaptive training regimens maximize retention of skills, minimize operator fatigue, create a new breed of clinician with technically accurate, confident, adaptable, a highly demanding modern dental environment.

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