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Knowledge, Attitude, and Perception Regarding 3D Printing Technology Among Undergraduate Dental Students: A Cross-Sectional Study

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Abstract

Background: Three-dimensional (3D) printing has emerged as an innovative technology with diverse applications in dentistry, including the fabrication of dental models, surgical guides, prostheses, and orthodontic appliances. Its integration into dental education offers opportunities to enhance preclinical training, improve visualization of anatomical structures, and support clinical treatment planning. However, students' knowledge, attitudes, and perceptions regarding this technology may influence its adoption in dental education and clinical practice.

Aim: This study aimed to assess the knowledge, attitudes, and perceptions regarding 3D printing technology among undergraduate dental students.

Materials and Methods: A cross-sectional questionnaire-based study was conducted among 200 undergraduate dental students. Data were collected using a structured questionnaire comprising 10 questions addressing awareness of 3D printing technology, knowledge of its dental applications, attitudes toward its

integration into the undergraduate curriculum, and perceptions of its potential benefits and limitations. The responses were analyzed using descriptive statistics and presented as frequencies and percentages.

Results: Of the 200 students, 142 (71%) reported awareness of 3D printing technology, while 116 (58%) were aware of its applications in dentistry. A total of 164 students (82%) believed that 3D printing could improve dental education, and 156 (78%) supported its incorporation into the undergraduate dental curriculum. Furthermore, 170 students (85%) expressed interest in receiving practical training in this technology. Regarding perceived barriers, 118 students (59%) identified the high cost of equipment as a potential limitation, while 96 (48%) considered limited practical exposure a barrier to learning.

Conclusion: The findings indicated favorable attitudes toward 3D printing technology among undergraduate dental students, particularly regarding its potential contribution to dental education and their willingness to receive practical training. However, gaps in awareness of its dental applications and concerns regarding implementation costs highlighted areas requiring attention. Integrating appropriate theoretical and practical training into undergraduate dental curricula may help improve students' familiarity with this emerging technology.

Keywords: Three-Dimensional Printing; Dental Education; Undergraduate Dental Students; Knowledge

Introduction

The advancement of digital technologies has significantly transformed contemporary dentistry by improving diagnostic accuracy, treatment planning, and clinical outcomes. Among these innovations, 3D printing, also known as additive manufacturing, has emerged as a promising technology with diverse applications in dental practice and education.[1,2] Unlike conventional subtractive manufacturing, which involves removing material from a solid block, 3D printing involves the layer-by-layer fabrication of physical objects from digital models. This process enables the production of customized structures with complex geometries, high reproducibility, and reduced material wastage.[3,4]

In dentistry, 3D printing has gained increasing attention across several specialties, including prosthodontics, orthodontics, oral and maxillofacial surgery, implantology, and pediatric dentistry.[5] Its applications include the fabrication of diagnostic models, surgical guides, orthodontic appliances, temporary restorations, complete denture components, and patient-specific anatomical models. The technology also facilitates the conversion of digital intraoral scans and cone-beam computed tomography data into physical models, supporting treatment planning and communication between dental professionals and patients. Furthermore, 3D printing has the potential to improve workflow efficiency and facilitate individualized treatment approaches.[6-8]

The integration of 3D printing into dental education offers additional opportunities to enhance students' learning experiences. Conventional preclinical training often relies on extracted teeth, typodonts, and commercially manufactured models, which may not fully represent the anatomical variations encountered in clinical practice. Three-dimensional printed models can provide standardized, reproducible, and patient-specific learning resources, allowing students to visualize complex anatomical structures and practice selected procedures in a controlled environment. Exposure to

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digital workflows during undergraduate education may also help students develop competencies relevant to technology-driven dental practice.[9,10]

Despite these potential benefits, the adoption of 3D printing technology in dental education may be influenced by several factors, including students' existing knowledge, attitudes, and perceptions. Limited exposure to the technology, inadequate institutional infrastructure, equipment and material costs, and insufficient practical training may restrict its effective implementation. Moreover, awareness of the technology does not necessarily indicate a comprehensive understanding of its underlying principles, available materials, clinical applications, or limitations. Assessing these dimensions is therefore important for identifying educational needs and planning appropriate curricular interventions.

Undergraduate dental students represent an important group for evaluating the educational readiness for emerging digital technologies. Their knowledge and attitudes may influence their willingness to engage with digital dentistry during training and their preparedness to incorporate these technologies into future clinical practice. A structured assessment of students' knowledge, attitudes, and perceptions can help identify areas of strength and deficiencies in current educational exposure. Such information may assist dental institutions in developing targeted educational activities, workshops, and practical training programs.

Although 3D printing has attracted considerable interest in dental research and clinical practice, evaluating students' awareness and acceptance remains important for its effective integration into undergraduate dental education. Therefore, the present study was conducted to assess the knowledge, attitudes, and perceptions regarding 3D printing technology among undergraduate dental students using a structured, 10-question questionnaire. The findings were intended to identify knowledge gaps, explore students' attitudes toward curricular integration, and assess their perceptions of the potential benefits and barriers associated with this technology.

Materials and Methods

Study Design and Study Population: A cross-sectional, questionnaire-based study was conducted to assess the knowledge, attitudes, and perceptions regarding three-dimensional 3D printing technology among undergraduate dental students. The study included 200 undergraduate dental students enrolled in a Bachelor of Dental Surgery (BDS). Data collection was carried out over a period of 1 month. Students who provided informed consent and agreed to participate were included in the study.

Questionnaire Design: Data were collected using a structured, self-administered questionnaire consisting of 10 questions developed to assess participants' knowledge, attitudes, and perceptions regarding 3D printing technology in dentistry. The questionnaire covered three principal domains: knowledge of 3D printing technology and its dental applications, attitudes toward its integration into undergraduate dental education, and perceptions regarding its potential benefits and implementation barriers.

The knowledge domain assessed students' awareness of 3D printing technology, its basic principles, and its applications in dentistry. The attitude domain explored students' opinions regarding the educational value of the technology, its incorporation into the undergraduate dental curriculum, and their willingness to participate in practical training. The perception domain addressed the

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anticipated benefits of 3D printing in clinical treatment planning and potential barriers, including equipment costs and limited practical exposure.

The questionnaire was administered in a format that allowed participants to select the response most appropriate to their knowledge or opinion. Responses were recorded for subsequent statistical analysis.

Data Collection Procedure: The questionnaire was distributed to eligible undergraduate dental students using online survey platform (Google Forms). Participants were informed about the purpose of the study, the voluntary nature of participation, and the confidentiality of their responses. Informed consent was obtained before questionnaire administration. Students were given sufficient time to complete the questionnaire independently, and responses were collected for analysis.

Statistical Analysis: The collected data were compiled and analyzed using [SPSS 24.0]. Categorical variables were summarized using frequencies and percentages. The responses to the 10 questionnaire items were analyzed to describe students' knowledge, attitudes, and perceptions regarding 3D printing technology. Where appropriate and supported by the study objectives, associations between categorical variables were assessed using the chi-square test or Fisher's exact test. A p-value of less than 0.05 was considered statistically significant for inferential analyses.

Ethical Considerations: Ethical approval was obtained from the Institutional Ethics Committee of before commencement of the study. Participation was voluntary, and informed consent was obtained from all participants before data collection. Confidentiality and anonymity were maintained during data handling and reporting. The study procedures were conducted in accordance with applicable institutional ethical requirements.

Results: A total of 200 undergraduate dental students participated in the study. Their responses to the 10-item questionnaire were analyzed to assess their knowledge, attitudes, and perceptions regarding three-dimensional (3D) printing technology in dentistry. The findings were categorized into knowledge, attitude, and perception domains and are presented as frequencies and percentages.

Knowledge Regarding 3D Printing Technology: Of the 200 participants, 142 (71%) reported awareness of 3D printing technology. However, 100 (50%) reported knowledge of its basic principles, and 116 (58%) were aware of its applications in dentistry. Furthermore, 110 students (55%) recognized the use of 3D printing for fabricating surgical guides (Table 1).

Attitudes Toward 3D Printing Technology: Most participants expressed favorable attitudes toward the integration of 3D printing into dental education. A total of 164 students (82%) believed that the technology could improve dental education, while 156 (78%) supported its inclusion in the undergraduate dental curriculum. Additionally, 170 participants (85%) expressed interest in receiving practical training in 3D printing technology (Table 2).

Perceptions Regarding 3D Printing Technology: Regarding perceived benefits and implementation barriers, 150 students (75%) believed that 3D printing could improve clinical treatment planning. However, 118 participants (59%) identified the high cost of equipment as a potential barrier, while 96 (48%) considered limited practical exposure a barrier to learning the technology (Table 3).

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Overall, the responses indicated favorable attitudes toward 3D printing technology and considerable interest in practical training. Nevertheless, the findings also highlighted potential gaps in students' familiarity with its applications and concerns regarding its implementation in undergraduate dental education.

Table 1: Knowledge Regarding 3D Printing Technology (N = 200)

Questionnaire item	Yes/Correct, n (%)	No/Incorrect
Awareness of 3D printing technology	142 (71.0)	58 (29)
Knowledge of the basic principles of 3D printing	100 (50.0)	100 (50)
Awareness of dental applications of 3D printing	116 (58.0)	84 (42)
Awareness of 3D printing for fabricating surgical guides	110 (55.0)	90 (45)

Table 2: Attitudes Toward 3D Printing Technology (N = 200)

Questionnaire item	Agree/Yes, n (%)	Disagree/No, n (%)
Belief that 3D printing could improve dental education	164 (82.0)	36 (18.0)
Support for incorporating 3D printing into the undergraduate dental curriculum	156 (78.0)	44 (22.0)
Interest in receiving practical training in 3D printing	170 (85.0)	30 (15.0)

Table 3: Perceptions Regarding 3D Printing Technology (N = 200)

Questionnaire item	Yes, n (%)	No, n (%)
Perception that 3D printing could improve clinical treatment planning	150 (75.0)	50 (25.0)
Perception that equipment costs could be a barrier to implementation	118 (59.0)	82 (41.0)
Perception that limited practical exposure was a barrier to learning	96 (48.0)	104 (52.0)

Discussion

Three-dimensional printing has emerged as an important technological advancement in dentistry, with applications in dental education, diagnostic procedures, treatment planning, and the fabrication of customized dental appliances.[11,12] Assessing undergraduate dental students' knowledge, attitudes, and perceptions regarding this technology is essential for understanding their preparedness to engage with emerging digital technologies. The present study evaluated these domains among 200 undergraduate dental students using a structured questionnaire comprising 10 questions.

The findings indicated that 71% of participants were aware of 3D printing technology, whereas 58% reported awareness of its applications in dentistry. Although general awareness appeared relatively high, familiarity with specific dental applications was comparatively lower. This difference suggests that recognizing the existence of a technology does not necessarily imply a comprehensive understanding of its practical applications. In dental education, students need exposure not only to the basic principles of additive manufacturing but also to its clinical relevance, including the fabrication of surgical guides, diagnostic models, orthodontic appliances, and prosthetic components. Incorporating these applications into undergraduate teaching may help bridge the gap between general awareness and practical knowledge.[13,14]

Regarding attitudes, 82% of participants believed that 3D printing could improve dental education, and 78%

supported its incorporation into the undergraduate dental curriculum. These findings suggested a favorable perception of the educational potential of 3D printing. Conventional preclinical teaching methods provide an essential foundation for developing clinical skills; however, 3D-printed models may complement these methods by providing reproducible anatomical structures and opportunities for repeated procedural practice. The ability to produce customized models may also facilitate the demonstration of anatomical variations and complex clinical scenarios. Nevertheless, the educational benefits of 3D printing depend on appropriate integration into teaching activities and should not be interpreted as evidence that the technology can replace conventional training methods.

An important finding was that 85% of participants expressed interest in receiving practical training in 3D printing technology. This response indicated considerable student interest in gaining hands-on experience with digital dental workflows. Practical training could introduce students to digital model preparation, computer-aided design, printer operation, material selection, and post-processing procedures. Workshops, demonstrations, and supervised preclinical exercises may provide opportunities to develop familiarity with these processes. However, willingness to participate in training does not necessarily indicate existing technical competence; therefore, future educational initiatives should include objective assessments of knowledge and practical skills.

Regarding perceived clinical benefits, 75% of participants believed that 3D printing could improve clinical treatment planning. This perception is consistent with the potential role of 3D printing in translating digital patient data into physical models that can support visualization, procedural planning, and communication. In selected clinical situations, patient-specific models and surgical guides may assist clinicians in understanding complex anatomy and preparing for procedures. Nevertheless, the clinical effectiveness and suitability of printed products depend on factors such as data quality, manufacturing accuracy, material properties, and appropriate clinical validation.[15]

Despite the favorable attitudes toward 3D printing, 59% of participants identified equipment cost as a potential barrier to implementation. The acquisition and maintenance of printers, software, materials, and associated equipment may impose financial challenges on educational institutions. In addition, the effective use of the technology requires trained faculty members, technical support, and suitable infrastructure. These considerations are particularly relevant when institutions plan to incorporate practical digital dentistry training into existing undergraduate curricula. Shared laboratory facilities, structured demonstrations, and collaborations with dental laboratories may offer potential approaches to improving access, although their feasibility will depend on institutional resources.

Furthermore, 48% of participants identified limited practical exposure as a barrier to learning. This finding highlights the potential importance of providing students with opportunities to observe and use 3D printing systems during their undergraduate education. Early exposure to digital technologies may help students develop an understanding of their capabilities and limitations. However, the relatively small proportion identifying limited exposure as a barrier should be interpreted cautiously because perceptions of educational needs may vary among students according to their previous experiences.

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Taken together, the findings suggested that favorable attitudes and interest in practical training may coexist with incomplete knowledge of specific dental applications and concerns about implementation. This distinction is important because successful integration of 3D printing into dental education requires more than student acceptance. It also requires appropriate curricular planning, infrastructure, faculty development, and objective evaluation of learning outcomes.

The present study had several limitations. First, its cross-sectional design captured participants' responses at a single point in time and did not establish causal relationships. Second, the use of a questionnaire may have introduced response bias, and self-reported familiarity may not accurately reflect actual technical knowledge or competence. Third, the assessment was based on 10 questions, which may not have captured all relevant aspects of 3D printing technology. Finally, the findings may not be generalizable to dental students from institutions with different levels of digital infrastructure or educational exposure. Future studies involving multiple institutions, larger samples, validated questionnaires, and objective knowledge assessments may provide a more comprehensive understanding of students' preparedness for 3D printing technology. Interventional studies could also evaluate whether structured training improves knowledge, confidence, and practical performance.

Conclusion

The present study assessed knowledge, attitudes, and perceptions regarding 3D printing technology among undergraduate dental students. The findings suggested favorable attitudes toward its potential role in dental education, with substantial interest in practical training and curricular integration. However, awareness of specific dental applications and concerns regarding equipment costs and practical exposure highlighted areas requiring further attention. Incorporating structured theoretical instruction and supervised practical training into undergraduate dental education may help students develop a better understanding of 3D printing and its potential applications. Further multicenter research using validated assessment tools and objective measures of knowledge and competency is recommended to guide the effective integration of this technology into dental curricula.

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