

ORIGINAL STUDIES

Integrating digital dentistry into education: perceptions and acceptance of chairside CAD/CAM technology among dental professionals and students

Andreea Kui¹, Iris Bara², Manuela Pripon², Antonela Berar¹, Smaranda Buduru¹

¹ Department of Prosthetic Dentistry and Dental Materials, Faculty of Dental Medicine, "Iuliu Hatieganu" University of Medicine and Pharmacy, Cluj-Napoca, Romania

² Cluj County Emergency Clinical Hospital, Cluj-Napoca, Romania

Abstract

Background. Digital dentistry, particularly Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) systems, has revolutionized restorative procedures by enhancing efficiency, precision, and clinical outcomes. However, its integration into dental education remains a challenge.

Aims. This study examines the perceptions and acceptance of chairside CAD/CAM technology among dental professionals and students, with a focus on its impact on training, clinical workflows, and patient outcomes.

Methods. A cross-sectional survey was conducted among 41 dental professionals and 47 dental students, primarily from Germany. Participants completed structured questionnaires assessing their exposure to CAD/CAM systems, satisfaction with training, perceived advantages and challenges, and future expectations.

Results. While 85% of students reported exposure to CAD/CAM, only 40% found their training adequate. Professionals expressed high satisfaction with CAD/CAM restorations, rating them superior in precision and efficiency compared to conventional techniques. Both groups acknowledged CAD/CAM's role in improving economic and aesthetic patient outcomes.

Conclusions. The findings highlight a strong need for enhanced training modules in dental education to optimize CAD/CAM technology's clinical benefits. Increased institutional support and curriculum adaptations are essential to ensure proficiency among future dental professionals.

Keywords: CAD/CAM technology, digital dentistry, dental education, clinical training, patient outcomes, professional acceptance.

Introduction

The development of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) systems in the 1980s marked a pivotal shift in dental technology, revolutionizing the approach to dental restorations (Afiqah Hamzah et al., 2021; Davidowitz & Kotick, 2011). Initially used for single unit restorations, these systems have rapidly evolved, now playing a crucial role in a wide range of dental procedures including the creation of inlays, onlays, crowns, and veneers (Pordeus et al., 2022; Liu, 2013; Miyazaki et al., 2013). The integration of CAD/CAM technology has not only enhanced the efficiency of dental practices but has also significantly improved the accuracy and customization of dental prosthetics (Rexhepi et al., 2023).

Recent advancements in intraoral scanning devices, dental software, and the materials used in CAD/CAM

systems have further broadened their applicability, ensuring seamless digital workflows that are becoming indispensable in modern dental practices (Abad-Coronel et al., 2023). As these technologies continue to evolve, they offer substantial benefits over traditional methods, such as reduced time for procedures, decreased material waste, and improved patient outcomes due to precise fittings and aesthetically pleasing results (Shi et al., 2022).

However, despite the technological benefits, the adoption of CAD/CAM systems in dental practices has the potential to be influenced by distinct factors such as cost, training requirements, and the perceived complexity of operating new systems (Tiu et al., 2019). Furthermore, there exists a spectrum of opinions among dental professionals and students regarding the impact of these systems on traditional dental craftsmanship and the future role of dental technicians (Kollmuss et al., 2016, Li et al.,

Received: 2025, February 17; Accepted for publication: 2025, February 26

Address for correspondence: Department of Prosthetic Dentistry and Dental Materials, Faculty of Dentistry, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, 32 Clinicilor Street, PC 400006, Cluj-Napoca, Romania

E-mail: antonela_berar@yahoo.com

Corresponding author: Antonela Berar; antonela_berar@yahoo.com

<https://doi.org/10.26659/pm3.2025.26.1.4>

2014, Aphol et al., 2001).

This study aimed to explore these varied and complex perceptions through a detailed survey of dental professionals and students, focusing on their experiences with, attitudes towards, and expectations of chairside CAD/CAM systems (Barengi et al., 2021, Nassani et al., 2021). By understanding these perspectives, the study aims to contribute to the ongoing discussion on the optimal integration and utilization of CAD/CAM technologies in dentistry, thereby paving the way for future advancements and educational frameworks (Yeslam et al., 2024).

The clinical outcomes of dental restorations are very strongly attached to the selection of materials employed. In the contemporary era, dental CAD-CAM (computer-aided design and computer-aided manufacturing) materials have significantly transformed the practice of dentistry on a daily basis (Shi et al., 2022).

Hypothesis

This study hypothesis was that dental professionals and students perceive CAD/CAM as a valuable advancement in modern dentistry and expect it to play an increasing role in future practice. While dental students are expected to report a high level of exposure to CAD/CAM systems during their training, many will perceive their training as inadequate, highlighting a gap between introduction and competence. In addition, dental professionals are expected to rate CAD/CAM restorations as superior to traditional methods in terms of efficiency, precision and patient satisfaction. Despite potential economic and technical barriers, both groups are expected to recognize CAD/CAM as an essential tool for the future of dentistry, reinforcing the need for wider adoption in education and clinical practice.

Material and methods

Research protocol

This study employed a cross-sectional, survey-based design to assess the perceptions, experiences, and acceptance of chairside Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology among dental professionals and students. The research aimed to evaluate CAD/CAM's integration into dental education and clinical practice, focusing on training adequacy, usability, and professional satisfaction.

a) Period and place of the research

The study was conducted between September and October 2023, with all responses collected anonymously. The study protocol was reviewed and approved by the Iuliu Hațieganu University of Medicine and Pharmacy Cluj-Napoca Ethics Committee (Approval No. 137/26.06.2023). Participation was voluntary, and responses were anonymous and confidential. All procedures adhered to the Declaration of Helsinki ethical guidelines for research involving human subjects.

b) Subjects and groups

A total of 88 participants were recruited, including 41 dental professionals and 47 dental students, primarily from Germany and Romania, with additional responses from other international institutions.

- Inclusion criteria: Participants were required to be

actively enrolled dental students (5th and 6th year) or practicing dental professionals with prior exposure to or experience with CAD/CAM systems.

- Exclusion criteria: Individuals without firsthand knowledge or usage of CAD/CAM technologies were excluded to maintain response validity.

Participants were invited via institutional email lists, academic networks, and professional dental associations.

c) Applied tests (Used instruments)

Two structured questionnaires were designed to assess CAD/CAM-related perceptions, training experiences, and professional use.

1. First questionnaire, titled "Assessing Students' Perspectives on CEREC Systems", was created by Andreea Kui and Iris Bara and aimed at evaluating the knowledge, opinions, and experiences of dental students regarding chairside CAD/CAM systems. The questionnaire included 20 items, with 15 focusing on CAD/CAM training, perception, and expected impact on future practice.

o The survey evaluated exposure to CAD/CAM technology in dental education, including training quality, willingness to adopt CAD/CAM in future practice, and perceived benefits or limitations.

o Contained 20 multiple-choice and Likert-scale items, covering aspects such as educational sufficiency, future career expectations, and economic feasibility.

o Only key responses were processed and analyzed based on their relevance to the study's objectives

2. Second questionnaire, titled "Assessing Professionals' Perspectives on CEREC Systems" authored by Antonela Berar and Manuela Pripon, was designed for dental professionals to assess their experiences, satisfaction, and clinical integration of CAD/CAM systems. The questionnaire contained 21 questions, 16 of which were directly relevant to the evaluation of CAD/CAM restorations.

o The survey examined clinical application and professional satisfaction, comparing CAD/CAM restorations to conventional methods.

o Included 21 items, assessing factors such as restoration quality, efficiency, patient satisfaction, and financial impact on dental practices.

o Given the focus of this study, only the most significant responses were analyzed and presented in the results section.

The survey was distributed electronically via Google Forms, with informed consent obtained at the beginning of the questionnaire. The survey remained open for three months to maximize participation.

d) Statistical processing

- Responses were recorded and stored in a secure database.

- Descriptive statistics (frequencies and percentages) were computed to analyze participant demographics, exposure levels, and satisfaction ratings.

- Inferential statistics (chi-square tests) were used to compare perceptions between students and professionals; statistical significance was set at $p < 0.05$.

Reliability and validity: the questionnaires were pre-tested with a small sample of dental students and professionals ($n=10$) to assess clarity and consistency.

Cronbach’s alpha was calculated to measure internal reliability, ensuring the robustness of survey items. To minimize response bias, all participants were blind to study hypotheses and provided their answers independently.

Results

a) Participant demographics

A total of 88 participants were included in the study, comprising 41 dental professionals and 47 dental students.

Dental professionals:

- The majority (90.2%) were from Germany, with smaller groups from Switzerland (7.3%) and Austria (2.5%).

- The gender distribution was predominantly male (78%), with females representing 22%.

- All participants were actively practicing in the dental field.

Dental students:

- The student cohort was more diverse, with 46.8% from Germany, followed by respondents from the USA (6.4%), Israel (8.5%), England (2.1%), Egypt (2.1%), Italy (4.2%), and Romania (8.5%).

- The gender distribution was more balanced, with 57% male and 43% female participants.

- All students were in their 5th or 6th year of dental studies and had exposure to CAD/CAM technology.

These demographics provided a well-rounded sample to assess perceptions of CAD/CAM technology among both early-career dental students and experienced professionals.

b) Experience and use of CAD/CAM systems

Dental professionals’ perceptions

- Quality of CAD/CAM restorations: A significant majority of professionals rated the quality of CAD/CAM restorations as either “Excellent” (49%) or “Very good” (37%) when compared to traditional lab-fabricated restorations.

- Satisfaction with CAD/CAM workflows: 73% of professionals reported being highly satisfied with CAD/CAM procedures, considering them more efficient and precise than conventional methods (Fig. 1).

- Clinical adoption and preference: Most professionals favored CAD/CAM for onlays, inlays, and crowns, with fewer recommending it for implant abutments.

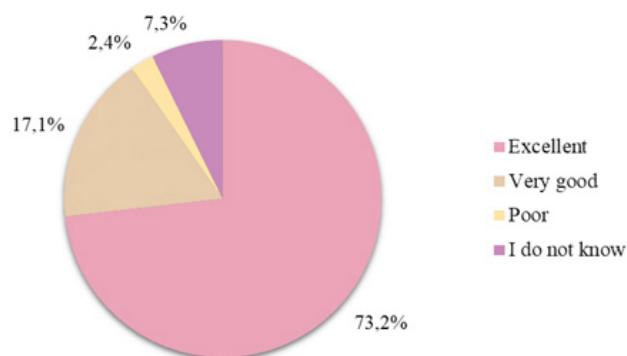


Fig. 1 – Satisfaction levels with CAD/CAM among professionals (“How do you evaluate your overall experience with CAD/CAM systems?”).

Students’ perspectives on CAD/CAM training

- Exposure to CAD/CAM: A substantial proportion of students (76%) had some degree of hands-on experience with CAD/CAM systems during their dental training (Fig. 2).

- Adequacy of training: despite high exposure levels, only 40% of students felt their training was sufficient to use CAD/CAM effectively in practice.

- Perceived advantages: 78% of students believed CAD/CAM technology improved both aesthetic and economic patient satisfaction, indicating strong support for its future integration into clinical practice.

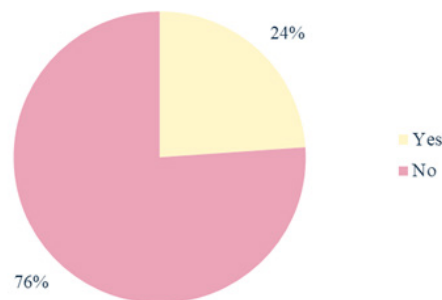


Fig. 2 – Student perceptions on the adequacy of CAD/CAM training (“Do you think your CAD/CAM training was sufficient?”).

c) Perceptions of CAD/CAM technology in future dentistry

- Growing importance in clinical practice: both professionals (92%) and students (89%) agreed that CAD/CAM technology will play a crucial role in the future of dentistry (Fig. 3).

- Economic considerations: while CAD/CAM was widely recognized for its efficiency and precision, students (78%) and professionals (68%) acknowledged high initial costs as a barrier to adoption.

- Impact on dental laboratories: a notable percentage of respondents expressed concerns regarding CAD/CAM’s impact on traditional dental laboratory workflows, with some professionals anticipating a shift in the role of lab technicians due to automation and in-office fabrication.

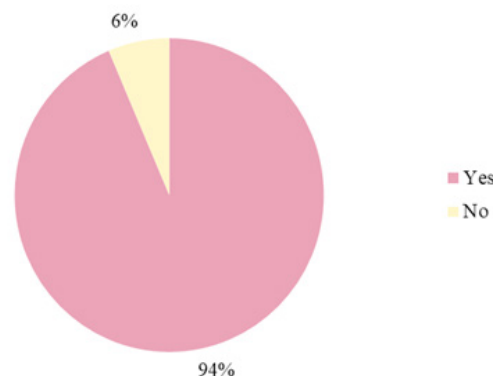


Fig. 3 – Expectations of CAD/CAM’s role in future dentistry across demographics (“Do you think that CAD/CAM has a big role in the future of dentistry?”).

Table I provides an overview of professionals' and students' perspectives on CAD/CAM technology, highlighting differences in satisfaction, training adequacy, and expectations for its future role in dentistry.

Table I
Summary of key survey responses.

Category	Professionals (% Agree)	Students (% Agree)
Quality Superior to Lab	86%	N/A
High Satisfaction	68%	N/A
Sufficient Training	N/A	40%
Future Role in Dentistry	92%	89%
Improves Economic Satisfaction	N/A	78%
Improves Aesthetic Satisfaction	N/A	78%

Discussion

Integration of CAD/CAM in dental education and practice

The findings of this survey indicate a prominent level of exposure to CAD/CAM technologies among dental students, with a significant majority reporting hands-on experience. This aligns with the increasing trend of incorporating advanced digital tools in dental education to prepare students for modern clinical environments (Kollmuss et al., 2016 & Li et al., 2014). However, the perceived insufficiency of training underscores a gap in educational curricula that may not fully meet the operational complexities of these systems. This suggests a need for enhanced training modules that provide deeper practical knowledge and troubleshooting skills, reflecting findings from Liu (2005) who emphasized the importance of comprehensive training to optimize the benefits of CAD/CAM technologies (Barengi et al., 2021).

Perceptions of quality and satisfaction

Dental professionals expressed high satisfaction with the quality of CAD/CAM restorations, reflecting a positive reception that could encourage wider adoption. The results support the work of Shi et al. (2022), who found that the superior material properties of CAD/CAM-produced restoratives contribute to their increasing popularity (Liu, 2005). The alignment of professional satisfaction with clinical outcomes indicates that despite the higher initial costs, the investment in CAD/CAM technology can be justified by the enhanced quality of patient care and efficiency (Miyazaki et al., 2013).

Economic and aesthetic impacts

Dental students find that CAD/CAM technologies simplify procedures and boost patient satisfaction. This dual benefit can be pivotal in dental practices, where patient outcomes and operational efficiency drive business success. Studies by Davidowitz & Kotick (2011) have highlighted similar trends, noting that the aesthetic precision and customization capabilities of CAD/CAM systems significantly improve patient-reported outcomes.

Future role of CAD/CAM in dentistry

The overwhelming consensus on the crucial role of CAD/CAM technologies in the future of dentistry displays the sector's readiness to embrace digital transformations. As discussed by Rexhepi et al. (2023), the ongoing advancements in CAD/CAM materials and techniques are

set to further revolutionize dental practices, making them an indispensable part of dental education and practice (Kollmuss et al., 2006). The anticipation of these systems replacing traditional techniques necessitates ongoing research and adaptation in educational frameworks to equip future dental professionals with the necessary skills and knowledge (Li et al., 2014 & Rexhepi et al., 2023).

Limitations and future research

While this study provides valuable insights into current perceptions and experiences with CAD/CAM technologies, the results are based on responses from Germany, which may not fully represent global perspectives. Future research should aim to include a more diverse international sample to explore cultural and educational differences in the adoption and utilization of CAD/CAM systems. Additionally, longitudinal studies could assess how perceptions and uses of CAD/CAM technologies evolve with further advancements and wider adoption across the field.

Conclusions

1. This study highlights the growing role of computer-aided design and computer-aided manufacturing (CAD/CAM) technology in modern dental education and in the professional practice of dentistry.
2. The results show a high level of exposure to CAD/CAM systems among dental students, but reveal a significant gap in training adequacy, suggesting the need for improved curriculum integration.
3. Dental professionals perceived CAD/CAM as a valuable tool for improving clinical efficiency, precision and patient satisfaction.
4. The majority of professionals rated CAD/CAM restorations as superior to conventional methods, particularly in terms of time efficiency and aesthetic outcomes.
5. However, challenges to wider acceptance remain, including economic barriers and the complexity of implementation.

Conflict of interest

No conflict of interest.

References

- Abad-Coronel C, Pazán DP, Hidalgo L, Larriva Loyola J. Comparative analysis between 3D-printed models designed with generic and dental-specific software. *Dent J* 2023; 11(9):216. doi: 10.3390/dj11090216.
- Afiqah Hamzah N, Razak NAA, Sayuti Ab Karim M, Gholizadeh H. A review of history of CAD/CAM system application in the production of transtibial prosthetic socket in developing countries (from 1980 to 2019). *Proc Inst Mech Eng H* 2021;235(12):1359-1374. doi: 10.1177/09544119211035200.
- Apholt W, Bindl A, Lüthy H, Mörmann WH. Flexural strength of Cerec 2 machined and jointed InCeram-Alumina and InCeram-Zirconia bars. *Dent Mater* 2001; 17(3):260-267. doi: 10.1016/s0109-5641(00)00080-4.
- Barengi L, Barengi A, Garagiola U, Di Blasio A, Gianni AB, Spadari F. Pros and cons of CAD/CAM technology for infection prevention in dental settings during COVID-19

- outbreak. *Sensors* 2021; 22:49. doi: 10.3390/s22010049.
- Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. *Dent Clin North Am.* 2011;55(3):559-ix. doi: 10.1016/j.cden.2011.02.011.
- Kollmuss M, Kist S, Goeke JE, Hickel R, Huth KC. Comparison of chairside and laboratory CAD/CAM to conventional produced all-ceramic crowns regarding morphology, occlusion, and aesthetics. *Clin Oral Investig* 2016; 20(4):791-797. doi: 10.1007/s00784-015-1554-9.
- Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: state of the art. *J Prosthodont Res* 2014; 58(4):208-216. doi: 10.1016/j.jpor.2014.07.003.
- Liu PR. A panorama of dental CAD/CAM restorative systems. *Compend Contin Educ Dent.* 2005; 26(7):507-518, 510, 512 passim; quiz 517, 527.
- Miyazaki T, Nakamura T, Matsumura H, Ban S, Kobayashi T. Current status of zirconia restoration. *J Prosthodont Res* 2013;57(4):236-261. doi: 10.1016/j.jpor.2013.09.001.
- Nassani MZ, Ibraheem S, Shamsy E, Darwish M, Faden A, Kujan O. A survey of dentists' perception of chair-side CAD/CAM technology. *Healthcare (Basel)* 2021; 9(1):68. doi: 10.3390/healthcare9010068.
- Pordeus MD, Santiago Junior JF, Venante HS, Bringel da Costa RM, Chappuis Chocano AP, Porto VC. Computer-aided technology for fabricating removable partial denture frameworks: A systematic review and meta-analysis. *J Prosthet Dent.* 2022;128(3):331-340. doi: 10.1016/j.prosdent.2020.06.006.
- Rexhepi I, Santilli M, D'Addazio G, Tafuri G, Manciocchi E, Caputi S, Sinjari B. Clinical applications and mechanical properties of CAD-CAM materials in restorative and prosthetic dentistry: A systematic review. *J Funct Biomater* 2023;14(8):431. doi: 10.3390/jfb14080431.
- Shi HY, Pang R, Yang J, Fan D, Cai H, Jiang HB, Han J, Lee ES, Sun Y. Overview of several typical ceramic materials for restorative dentistry. *Biomed Res Int* 2022;2022:8451445. doi: 10.1155/2022/8451445.
- Tiu J, Belli R, Lohbauer U. Contemporary CAD/CAM materials in dentistry. *Curr Oral Health Rep* 2019; 6:250-256. doi: 10.1007/s40496-019-00236-3.
- Yeslam HE, Freifrau von Maltzahn N, Nassar HM. Revolutionizing CAD/CAM-based restorative dental processes and materials with artificial intelligence: a concise narrative review. *PeerJ* 2024; 12:e17793. doi: 10.7717/peerj.17793.