Original Article

Knowledge, Awareness, and Practice of CAD/CAM Technology Among Dental Students

Sara Hwisa¹* [ID], Fatma Esmeda² [ID], Amjed Alrimieh³ [ID], Khalid Omar⁴ [ID], Ali Milad⁵ [ID]

¹Department of Medical and Basic Sciences, Faculty of Dentistry, University Sabratha, Libya
²Department of Prosthodontics, Faculty of Dentistry, Zawia University, Libya
³Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Zawia University, Libya
⁴Department of Prosthodontics, Faculty of Dentistry, University of Tripoli, Libya
⁵Faculty of Dentistry, Zawia University, Libya
Corresponding Email. *Sara.ab.mu.hw@gmail.com*

Abstract
The adoption of Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) technology in dentistry has transformed clinical practices, but its integration remains limited among dental students. The purpose of this study is to evaluate the knowledge, awareness, and practice of CAD/CAM technology among final-year dental students. A descriptive survey was administered to final-year dental students across public colleges using a validated structured questionnaire. The instrument covered demographic characteristics, knowledge of CAD/CAM clinical applications, awareness of digital systems and materials, practical training exposure, perceived advantages, and implementation barriers. Descriptive statistical analyses were performed using SPSS software (version 21; IBM Corp.). Most participants (63.9%) were aware of CAD/CAM clinical applications, with crown/bridge fabrication (66.4%) and digital impressions (50.4%) being the most recognized uses. However, only 17.6% had attended CAD/CAM training. High cost (63.6%) and insufficient training (16.9%) were cited as key barriers. Despite this, 79% believed CAD/CAM represents dentistry's future, and 66.4% preferred it over conventional methods. Gender differences emerged: males reported higher engagement with crown/bridge fabrication, while females recognized smile design and onlays/inlays more frequently. Materials like zirconia (51.3%) and E-Max (40.3%) were well-known, yet 38.7% lacked material knowledge. Final-year dental students demonstrate awareness of CAD/CAM, but practical adoption is hindered by cost and infrastructure challenges. Enhanced digital dentistry training in dental curricula could facilitate broader integration into clinical practice.
Keywords: Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Digital Dentistry, Dental Education, Prosthodontics.

Introduction

Computer-aided design/computer-aided manufacturing (CAD/CAM) technology has revolutionized modern dentistry by enhancing precision, efficiency, and overall treatment outcomes. Advancements in both milling and 3D printing techniques have enabled the fabrication of restorations with high accuracy and reduced turnaround times, positioning CAD/CAM as an integral component of contemporary dental practice [1]. The digital era has heralded a paradigm shift in dentistry, compelling clinicians and educators alike to re-evaluate traditional workflows and integrate novel digital strategies into both clinical and academic settings [2].

Recent studies have revealed considerable variability in the extent of knowledge, awareness, and practical engagement with digital technology among dental professionals. While an expanding theoretical understanding of digital applications in dentistry is evident, significant deficiencies persist in hands-on training and implementation [3]. Furthermore, participation in pre-clinical elective courses has been associated with marked improvements in dental students' proficiency with intraoral scanners and other CAD/CAM systems, thereby cultivating a more favorable perspective on digital workflows [4].

Systematic reviews and national surveys further corroborate that while the acceptance of CAD/CAM technology is on the rise, comprehensive integration into dental curricula is still lacking. Evidence suggests that although many dental students express favorable attitudes towards digital dentistry, there is a persistent need for more hands-on training and structured educational modules to bridge the gap between theory and practice [5,6]. Additional studies from diverse regions, including the Makkah region of Saudi Arabia, reinforce that awareness levels are inconsistent among undergraduates, often correlating with the degree of practical exposure offered by their institutions [7]. Furthermore, clinical and laboratory evaluations have demonstrated the effectiveness of digital fabrication methods in producing high-quality removable acrylic dentures and ceramic restorations, thus supporting the clinical viability of these technologies [8–10]. This study aims to assess the knowledge, awareness, and practical application of CAD/CAM technology among final-year dental students and to identify the factors influencing their adoption of digital dentistry in clinical practice.

Methods
Study Design and Setting
A descriptive survey design was employed to evaluate the knowledge, awareness, and practice of CAD/CAM technology among final-year dental students. The study was conducted in public dental colleges, thereby providing a representative snapshot of the current state of digital dentistry education.

Study Population and Sampling
The target population comprised final-year dental students enrolled in accredited dental programs at the Faculty of Dentistry, Zawia University. To minimize selection bias and ensure a representative sample, participants were chosen using a random sampling approach. The inclusion criteria specified that participants must be in their final year of dental studies and willing to provide informed consent.

Questionnaire Development
A structured questionnaire was developed following an extensive review of the literature and previous studies evaluating CAD/CAM technology in dentistry [11-19]. The instrument was designed to capture information across several domains: Demographic Characteristics: Age, gender, clinical experience (categorized as <5 years, 5–10 years, >10 years, or N/A), and place of work. Knowledge of Digital Procedures: Familiarity with various CAD/CAM applications (e.g., crown and bridge fabrication, impression making, smile designing, onlay/inlay restorations). Awareness of CAD/CAM Systems and Materials: Recognition of specific systems (e.g., intraoral scanners, CEREC, Lava™, etc.) and materials used in digital workflows (e.g., zirconia, E Max, composite PMMA). Practice and Training: Participation in CAD/CAM training programs, perceived advantages (e.g., reduced chairside time, fewer appointments) and shortcomings (e.g., high cost, lack of infrastructure), and attitudes toward integrating digital technology into future clinical practice.
The questionnaire underwent pilot testing on a sample of ten dental students to ensure clarity, relevance, and content validity. Feedback from this phase was used to refine the instrument before full-scale administration.

Data Collection Procedure
Data were collected in June 2024 using both online and paper-based questionnaires to maximize reach and participation. Participants received a brief explanation of the study objectives, and written informed consent was obtained prior to survey completion. The data collection spanned one month, ensuring timely responses and minimizing potential recall bias.

Data Analysis
Responses were coded and entered into the Statistical Package for the Social Sciences (SPSS) software (version 21; IBM Corp., Armonk, NY, USA) for analysis. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed for all variables to summarize the data effectively.

Ethical Considerations
The study protocol was reviewed and approved by the Department of Fixed Prosthodontics in the faculty of Dentistry. All participants were assured of confidentiality and anonymity, and data were handled in strict compliance with ethical research guidelines. Informed consent was obtained from all respondents prior to their inclusion in the study.

## Results
Demographic Characteristics
The survey included 119 participants, with a female predominance (83.2%, n = 99) compared to males (16.8%, n = 20). The mean age was comparable across genders (males: 22.95 ± 0.83; females: 22.97 ± 0.79). A majority (61.3%, n = 73) reported no clinical experience (N/A), while 36.1% (n = 43) had <5 years. Most worked in public universities (40.3%, n = 48) or dental schools (29.4%, n = 35). Gender-specific analysis revealed males more frequently worked in public universities (55.0% vs. 37.4% females), while females were distributed across private clinics (29.3%) and dental schools (31.3%) (see Figure 1).
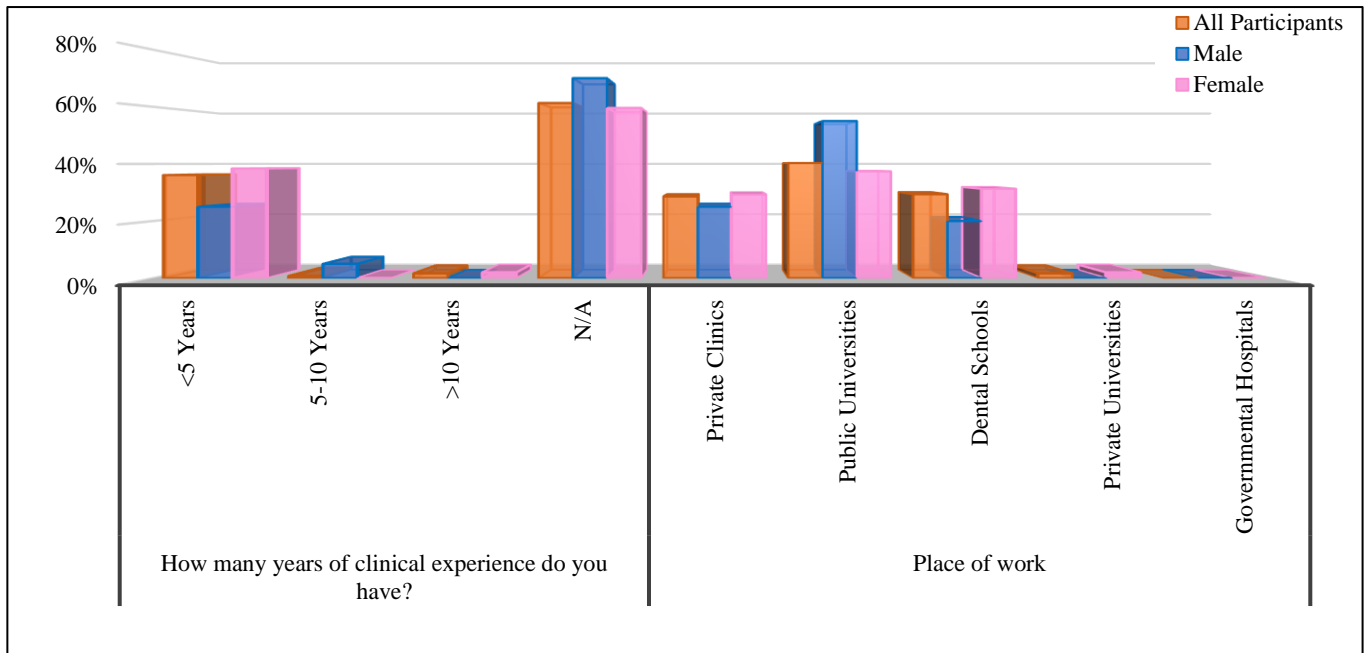
Figure 1. Demographics of Participants.

Perceptions of CAD/CAM Applications
### Procedures deemed useful:
Crown and bridge fabrication (66.4%, n = 79) and digital impressions (50.4%, n = 60) were most recognized. Gender differences emerged: males reported higher use of crown/bridge fabrication (70.0% vs. 65.7% females), whereas females more frequently identified onlay/inlay (36.4% vs. 10.0%) and smile designing (48.5% vs. 30.0%) (Figure 2).
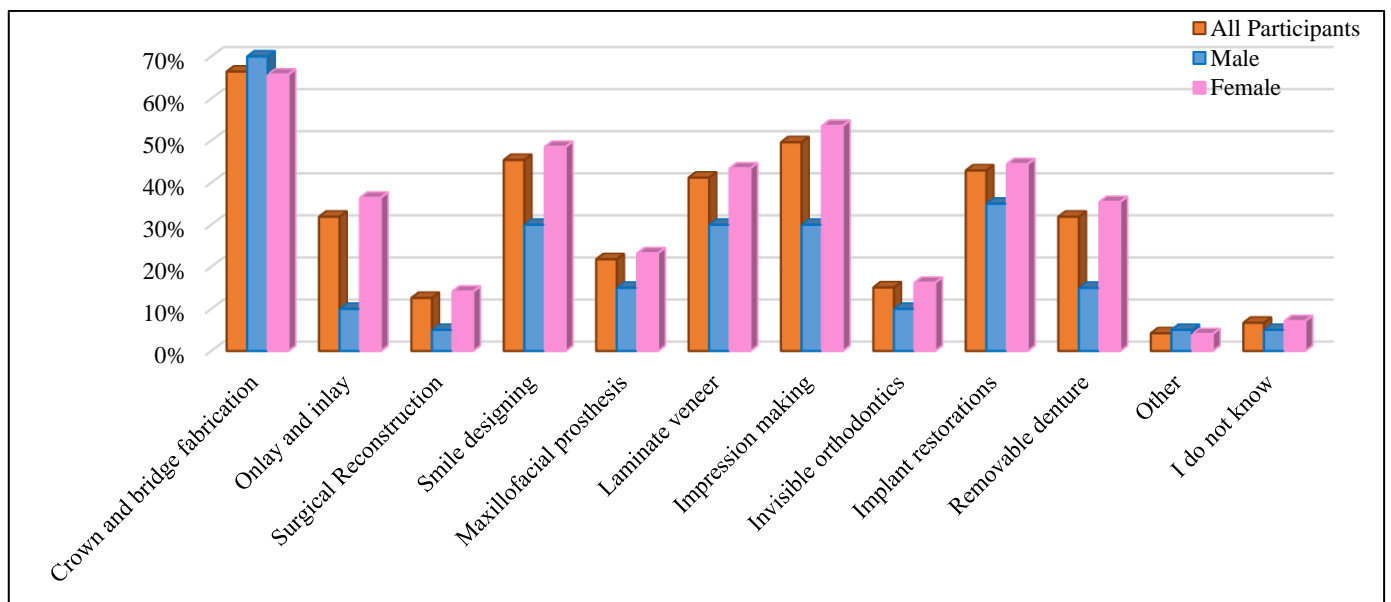
Figure 2. Digital technology provides useful procedures for dentistry.

Applications of CAD/CAM in dentistry
Intraoral scanners (42.4%, n = 50) and digital smile design (27.1%, n = 32) were most recognized. A notable proportion (33.9%, n = 40) reported no awareness of any system, with males more likely to select "none" (35.0% vs. 33.7% females) (see Figure 3).
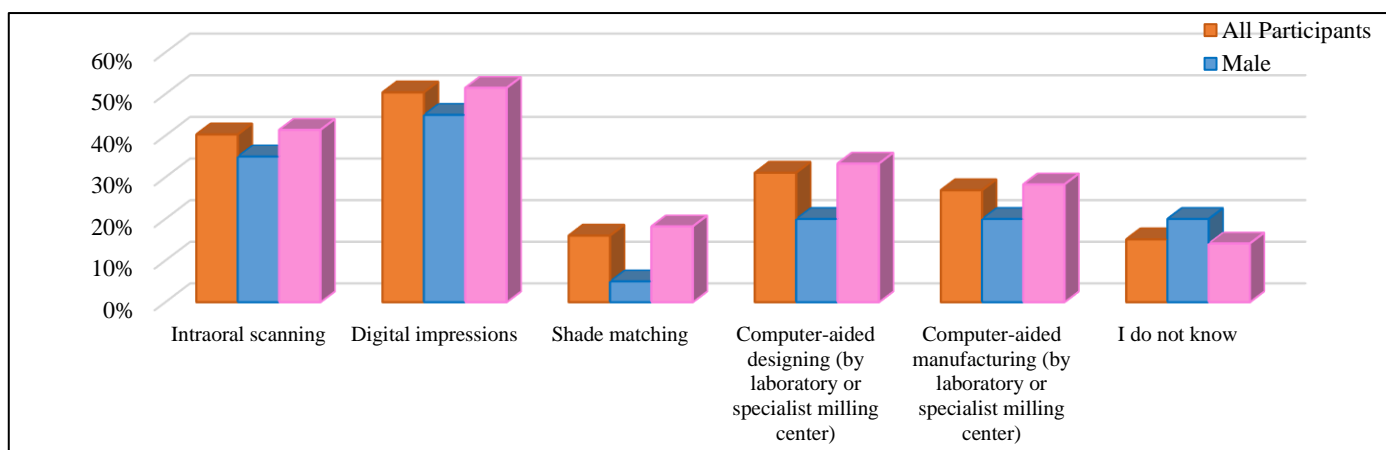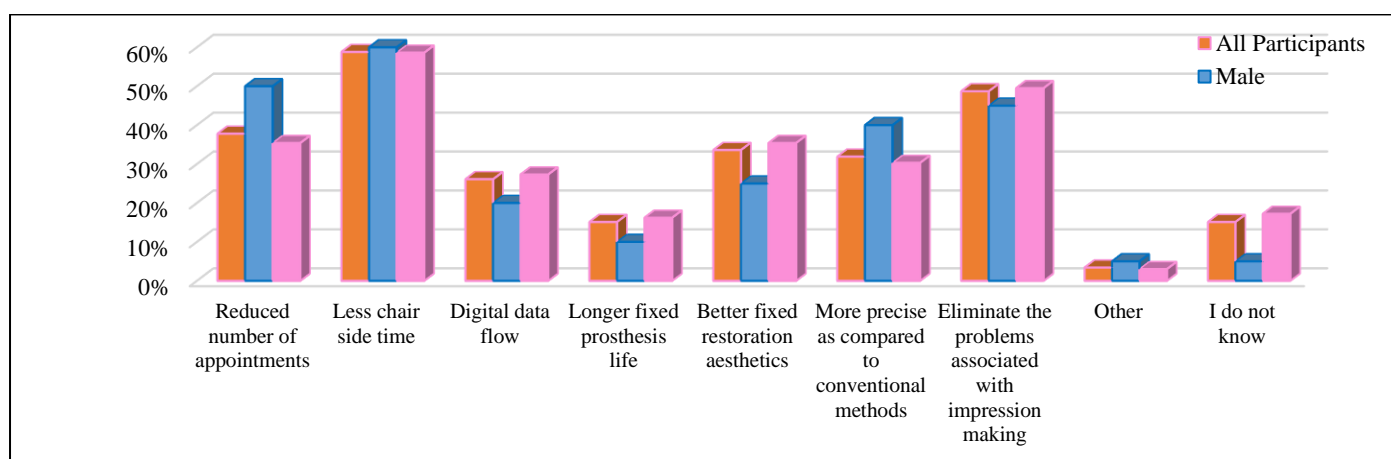
Figure 3. Applications of CAD/CAM in dentistry

Advantages and Shortcomings of CAD/CAM
### Advantages of CAD/CAM

Reduced chairside time (58.8%, n = 70) and eliminating impression-related issues (48.7%, n = 58) were the top benefits. Males emphasized reduced appointments (50.0% vs. 35.4% females) (Figure 4).

Figure 4. Advantages of CAD/CAM

Shortcomings of CAD/CAM

High cost (63.6%, n = 75) was the primary barrier. Males cited lack of training more frequently (30.0% vs. 14.3% females), while females reported higher "I do not know" responses (32.7% vs. 20.0%) (Figure 5).
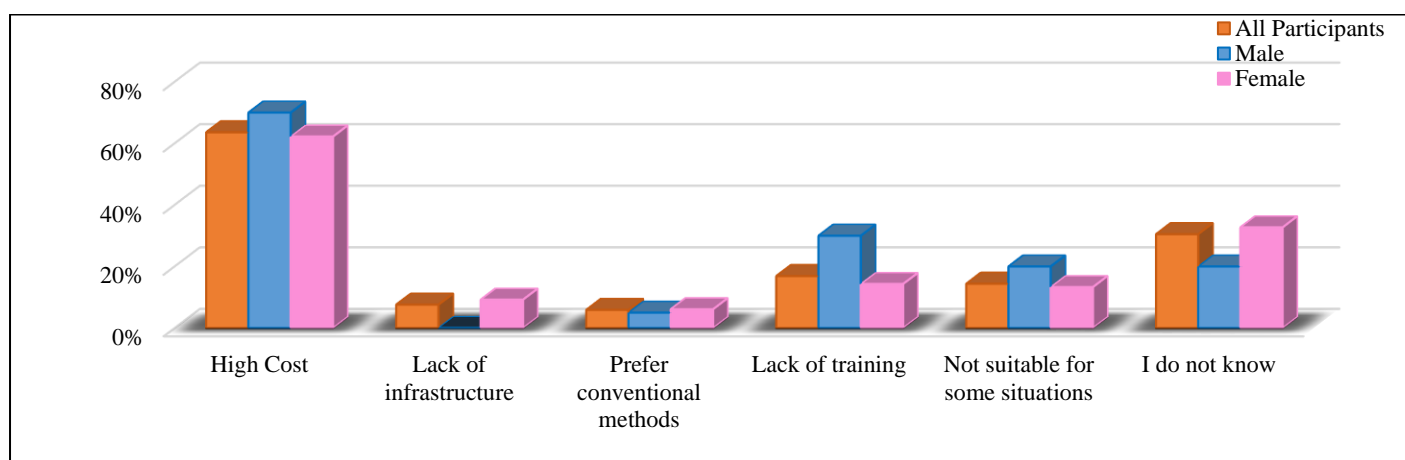
*Figure 5. The implementation of CAD/CAM technology in practice presents various shortcomings.*

Awareness of CAD-CAM technology's clinical applications in dentistry

Clinical applications: 63.9% (n = 76) were aware of CAD/CAM uses, with higher female awareness (65.7% vs. 55.0% males) (Figure 6).
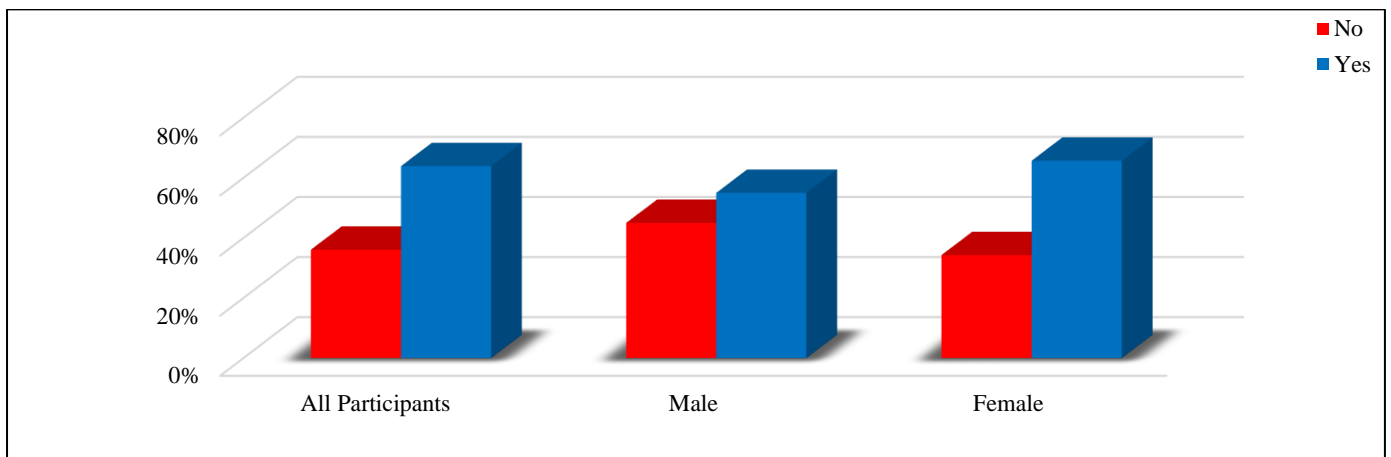
Figure 6. Awareness of CAD-CAM technology's clinical applications in dentistry

Male and female students differed in their awareness of specific CAD/CAM systems. No males were aware of Lava™ or DCS Precident, while 9.2% of females were. Awareness of CEREC was higher among females (16.3% vs. 5.0%). Intraoral scanners were the most recognized (40.0% of males, 42.9% of females), and about one-third of both groups (35.0% males, 33.7% females) were unaware of any system (Figure 7).
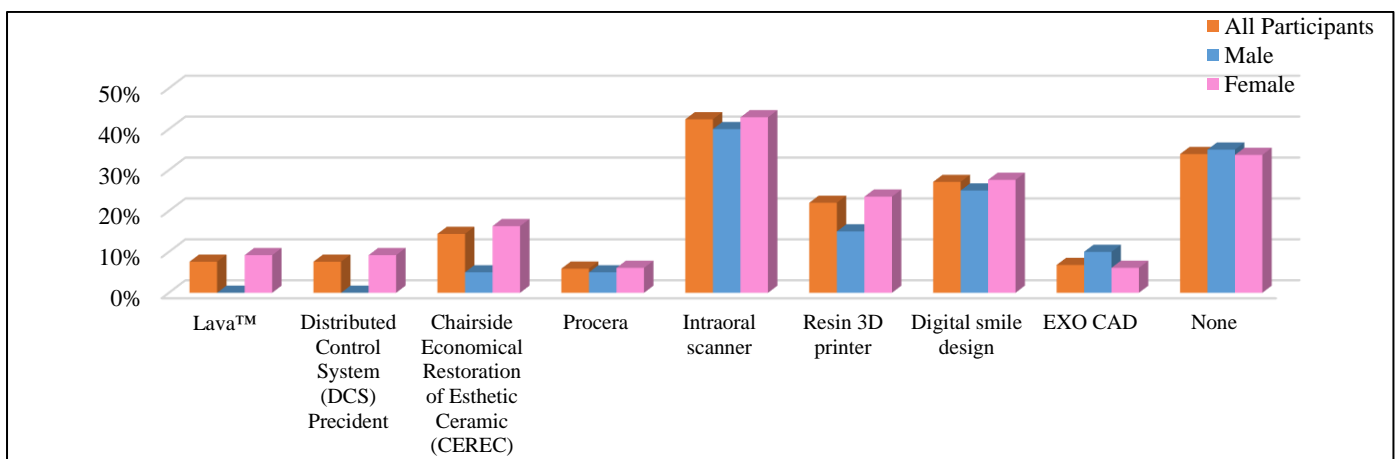
Figure 7. Awareness of various CAD-CAM systems in dentistry

Materials Used with CAD/CAM Systems in Dentistry
Materials used with CAD/CAM: Zirconia (51.3%, n = 61) and E-Max (40.3%, n = 48) were most recognized. However, 38.7% (n = 46) reported no knowledge, particularly males (40.0% vs. 38.4% females) (see Figure8).
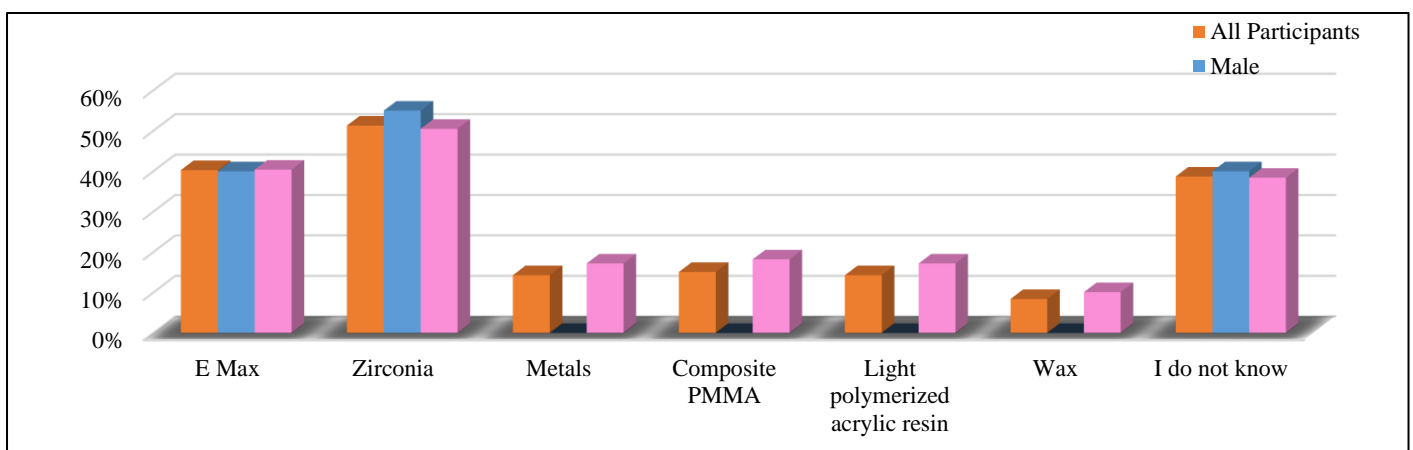
Figure 8. Various materials are used with CAD-CAM systems in dentistry.

Practice and Attitudes Toward CAD/CAM Systems in Dentistry

The study revealed that a majority of dental students have not received training on CAD/CAM systems, with 82.4% reporting no formal training (80% males, 82.8% females). Despite this, there is strong support for increasing digital dentistry education in undergraduate and postgraduate courses (69.7% overall, 80% males). Most participants showed a keen interest in incorporating CAD/CAM into their clinical workflow (52.9%), preferring it over conventional methods (66.4%). Additionally, 61.3% believed digital dentistry would influence their clinical decisions, and 79% agreed it would positively impact the future of the dental profession. Furthermore, 61.3% felt removable partial dentures could be digitally designed, with notable differences between genders in their responses. These findings underscore a growing interest in CAD/CAM systems, despite the need for more comprehensive training and education (Figure 9).

Figure 9. Practices and Perceptions of CAD/CAM Systems Among Dental Students.

Discussion

The present study evaluated the knowledge, awareness, and practice of CAD/CAM technology among final-year dental students. The findings revealed that the majority of respondents were female (83.2%) with a mean age of approximately 23 years. The gender distribution in our study aligns with similar studies conducted by Nayakar et al. (2022) and Gad et al. (2025), which also reported a higher representation of female dental students. [3,11].

Most participants had less than five years of clinical experience (36.1%) or were yet to start clinical practice (61.3%). This is consistent with the study by Shetty et al. [7], which also found that dental students had limited exposure to clinical CAD/CAM applications. Public universities (40.3%) and dental schools (29.4%) were the primary workplaces, which supports previous studies indicating that institutional settings are the primary exposure points for CAD/CAM technology [6].

Approximately 63.9% of the respondents were aware of CAD/CAM clinical applications, comparable to Wu (2024), Hall et al. (2023), and Sri et al. (2023) [1,12, 13], who reported awareness rates of 60–70% among dental students. However, practical utilization remains limited, with only 17.6% attending a training program, similar to findings by Dhokar et al. (2020) [14], where inadequate training was cited as a major barrier to CAD/CAM adoption.

Our study found that crown and bridge fabrication (66.4%) and digital impressions (50.4%) were the most commonly recognized CAD/CAM applications. These findings parallel Wu CJ (2024) [1] which underscored the efficacy of CAD/CAM systems in fabricating accurate restorations. Suganna et al. (2024) and Kuang et al. (2022) [2,10], highlighted those prosthetic restorations remain the dominant CAD/CAM utilization areas. Digital smile design (45.4%) was also noted, aligning with Verkhovskiy et al. (2023) [8], who emphasized its growing role in esthetic dentistry. However, advanced procedures such as surgical reconstruction and invisible orthodontics were less recognized, suggesting a gap in the exposure to the full range of digital applications—a trend also reported by Nayakar et al. (2022) [3], who observed limited practical knowledge.

The study also found that a significant number of students were aware of intraoral scanning (42.4%) and digital impressions (50.4%), reflecting a growing familiarity with these technologies. These results are in line with the work by Zoidis et al. (2022) [4], who reported enhanced awareness of CAD/CAM systems following targeted pre-clinical elective courses. Nevertheless, approximately one-third of respondents (33.9%) were not aware of any specific CAD/CAM systems, indicating that theoretical knowledge does not necessarily translate into comprehensive system-specific familiarity.

Regarding the advantages of CAD/CAM, the respondents highlighted reduced chairside time (58.8%) and elimination of conventional impression problems (48.7%) as significant benefits. These perceptions are consistent with earlier studies that have documented the efficiency and precision of digital workflows in reducing patient appointments and enhancing restorative outcomes [5,6], findings similar to Chobe et al. (2023) and Palanisamy et al. (2019) [15,16]. High cost (63.6%) was identified as the main limitation, consistent with Imran et al. (2024) [17], who noted that financial constraints hinder adoption. Despite these benefits, high cost was identified as the primary shortcoming by 63.6% of participants. This concern mirrors previous findings that have identified financial constraints and infrastructural limitations as major barriers to the adoption of digital dentistry.

Zirconia (51.3%) and E-Max (40.3%) were the most recognized materials used in CAD/CAM systems, in agreement with Imran et al. (2024) [17], who reported that zirconia is the preferred material for digital fabrication. However, 38.7% of participants were unaware of CAD/CAM-compatible materials, highlighting an educational gap.

Future Implications and Recommendations

A significant proportion (79%) believed that CAD/CAM technology represents the future of dental practice, supporting findings by Lauricia et al. (2024) [18]. However, limited hands-on training remains a barrier, reinforcing the conclusions of Alhoumaidan et al. (2019) and Islam et al. (2024) [19,20] that digital dentistry curricula should be expanded in undergraduate programs. Furthermore, only 17.6% of the students had participated in any CAD/CAM training programs or workshops, despite a substantial majority expressing a desire to incorporate digital workflows into their future practice (52.9% interested; 66.4% preferred CAD/CAM over conventional methods). These results underscore a disconnect between theoretical awareness and practical application, as also noted by Acharya et al. [9], who reported limited practical exposure regarding 3D printing and CAD/CAM technology. Clinical studies, such as that by Kuang et al. [10], further support the clinical viability of CAD/CAM systems in producing high-quality restorations, suggesting that increased practical training could improve clinical decision-making and outcomes.

Conclusion

In conclusion, while dental students display a positive attitude toward CAD/CAM technology, the implementation of such systems remains hindered by cost and insufficient infrastructure. To bridge this gap, it is imperative to enhance educational programs, provide targeted training, and explore cost-effective solutions that would allow students to fully integrate CAD/CAM technologies into their future clinical

practices. This study underscores the need for continued research and development to facilitate the widespread adoption of digital technologies in dentistry, ensuring that dental professionals are equipped to meet the demands of modern dental care.

Acknowledgments
None.

Conflicts of Interest
There are no conflicts of interest.

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المستخلص

أدى اعتماد تقنية التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب في طب الأسنان إلى إحداث تحول في الممارسات السريرية، إلا أن تكاملها لا يزال محدودا بين طلاب طب الأسنان. تهدف هذه الدراسة إلى تقييم المعرفة والوعي والممارسة لتقنية التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب بين طلاب السنة النهائية في طب الأسنان. أجري استطلاع وصفي لطلاب السنة النهائية في طب الأسنان في الكليات الحكومية باستخدام استبيان منظم معتمد. غطت الأداة الخصائص الديموغرافية، ومعرفة التطبيقات السريرية لتقنية التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب، والوعي بالأنظمة والمواد الرقمية، والتعرض للتدريب العملي، والمزايا المدركة، وعوائق التنفيذ. أجريت التحليلات الإحصائية الوصفية باستخدام برنامج) SPSS الإصدار 21؛ شركة .(IBM كان معظم المشاركين (63.9٪) على دراية بالتطبيقات السريرية لتقنية التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب، حيث كانت صناعة التيجان/الجسور (66.4٪) والطبعات الرقمية (50.4٪) أكثر الاستخدامات شهرة. ومع ذلك، لم يحضر سوى 17.6 ٪ تدريبا على تقنية التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب. أشير إلى التكلفة العالية (63.6٪) ونقص التدريب (16.9 ٪) كعائقين رئيسيين. ومع ذلك، رأى 79 ٪ أن تقنية التصميم بمساعدة الحاسوب تمثل مستقبل طب الأسنان، وفضلها 66.4 ٪ على الطرق التقليدية. وبرزت فروق بين الجنسين: فقد أفاد الذكور باهتمام أكبر بتصنيع التيجان والجسور، بينما تعرفت الإناث على تصميم الابتسامة والحشوات/الحشوات الداخلية بشكل أكبر. وكانت مواد مثل الزركونيا (51.3 ٪) وإيماكس (40.3٪) معروفة جيدا، إلا أن 38.7 ٪ منهم يفتقرون إلى المعرفة بالمواد. ويظهر طلاب السنة النهائية في طب الأسنان وعيا بتقنية التصميم بمساعدة الحاسوب. إلا أن التطبيق العملي يعيقه التكلفة وتحديات البنية التحتية. ويمكن أن يسهل تعزيز التدريب على طب الأسنان الرقمي في مناهج طب الأسنان دمجا أوسع في الممارسة السريرية.