The Impact of Digital Manufacturing in Dentistry on Dental Technicians' Jobs: A Case Study of Libyan Dental Laboratories

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Abstract:

This study explores the global transition to digital manufacturing in dentistry, focusing on how CAD/CAM and 3D printing technologies are influencing Libya's dental sector. Specifically, it investigates the impact of these technologies on the professional roles and job security of dental technicians. Using a mixed-methods approach, data were collected from 50 dental technicians across 15 laboratories in Libya through surveys and semi structured interviews, supplemented by case studies comparing traditional and digital workflows. The findings reveal significant barriers to adoption, including the high cost of equipment, limited access to specialized training, and resistance to change among traditionally trained technicians. This study concludes that the risk of job loss is not caused by the technology itself, but by the digital gap and the lack of formal training. Consequently, the survival of dental technicians in the evolving Libyan market depends on their ability to transition from manual crafters to digital specialists.

Keywords: Digital Manufacturing, CAD/CAM System, Libya Dental Sector, Dental Technicians, 3D Printing.

Introduction

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) and 3D printing, has revolutionized various aspects of dental practice, from diagnostics and treatment planning to the fabrication of dental prosthetics (Neto *et al.,* 2024; Mykhaylyuk *et al.,* 2024; Farook *et al.,* 2020) . These technologies promise enhanced precision, efficiency, and customization, ultimately leading to improved patient outcomes and streamlined workflows in dental laboratories (Gomez-Polo *et al.,* 2024; Ahmad *et al.,* 2024). Globally, the shift towards digital dentistry is well underway, with an increasing number of dental professionals and laboratories adopting these innovative tools. However, the pace and extent of this adoption vary significantly across regions, often influenced by economic conditions, technological infrastructure, and the availability of skilled personnel (Xi, R *et al.,* 2024; Zandinejad *et al.,* 2025). In developing countries, the transition to digital manufacturing in dentistry can be particularly challenging, as it requires substantial initial investment, access to specialized training, and a supportive regulatory environment. Libya's dental sector is no exception to this global trend. While there is a growing awareness and gradual integration of digital technologies, the country faces unique challenges that may impede a smooth transition. These challenges include economic constraints, social factors, and limitations in infrastructural development, which can affect the accessibility and affordability of advanced digital equipment and training programs (El-Kishawi *et al.,* 2024; Abushahma *et al.,* 2024). Understanding how these factors influence the adoption of digital manufacturing and its impact on the dental workforce is crucial for developing effective strategies to support the industry's evolution. This study aims to investigate the impact of digital manufacturing on the roles and job security of dental technicians in Libya.

Material and Methods

This study employed a mixed-methods approach to comprehensively investigate the impact of digital manufacturing on dental technicians' jobs in Libyan dental laboratories. The research design combined quantitative data collection through surveys with qualitative insights gathered from semi-structured interviews and case studies.

Study Population and Sampling

The target population for this study comprised dental technicians working in various dental laboratories across Libya. A convenience sampling method was utilized to recruit participants. A total of 50 dental technicians from 15 different laboratories in Libya participated in the survey. This sample size, while not exhaustive, provides a representative snapshot of the experiences and perceptions within the Libyan dental technology sector.

Data Collection Instruments
Survey Questionnaire

A structured questionnaire was developed to collect quantitative data on demographic information, current job roles, adoption of digital technologies, perceived impacts of digitalization, challenges faced, and training needs. The questionnaire included both closed-ended (e.g., multiple-choice, Likert scale) and open-ended questions to capture a wide range of responses. The survey was administered to participants in a manner that ensured anonymity and confidentiality.

Semi-structured Interviews

To gain deeper qualitative insights, semi-structured interviews were conducted with a subset of dental technicians and laboratory owners. These interviews explored participants' experiences, opinions, and perspectives on the digital transformation in more detail, allowing for the exploration of nuanced views and unexpected themes. The interview guide covered topics such as the practical implications of digital technologies, changes in daily tasks, skill development, and future outlook.

Case Studies

To provide contextual understanding, case studies of selected traditional and digitally equipped dental laboratories were conducted. These case studies involved observations of workflows, discussions with staff, and analysis of the types of equipment and processes utilized. This allowed for a comparative analysis of the operational differences and challenges faced by laboratories at various stages of digital adoption.

Results and Discussion

This section presents the key findings from the survey data, providing a detailed overview of the demographic characteristics of the dental technicians surveyed, their current engagement with digital technologies, and their perceptions regarding the impact of digitalization on their profession.

Table 1 Educational Qualifications

Qualification	Frequency	Percentage	Cumulative Percentage
Bachelor's	22	44.0	44.0
Diploma	12	24.0	68.0
Master's/PhD	16	32.0	100.0
Total	50	100.0	

In terms of educational background, Bachelor's degree holders are the most prevalent, accounting for 44% (n=22) of the respondents. Master's/PhD holders comprise a significant 32% (n=16), while Diploma holders make up 24% (n=12). This indicates a relatively high level of education among the dental technicians in the sample, with a substantial number possessing advanced academic qualifications.

Table 2 Years of Experience in Dental Technology

Experience (Years)	Frequency	Percentage	Cumulative Percentage
11 - 15 years	6	12.0	12.0
11 - 15 years, more than 15 years	1	2.0	14.0
5 - 10 years	8	16.0	30.0
Less than 5 years	9	18.0	48.0
More than 15 years	26	52.0	100.0
Total	50	100.0	

The experience level of the dental technicians surveyed is notably high, with over half (52%, n=26) having more than 15 years of experience in the field. This is followed by those with less than 5 years of experience (18%, n=9) and 5-10 years (16%, n=8). A small percentage (2%, n=1) reported experience in both 11-15 years and more than 15 years, suggesting a nuanced understanding of their career progression. The high proportion of experienced professionals underscores the potential for a deep understanding of industry changes.

Table 3 Digital Technologies Used (Frequency & Percent)

Technology	Frequency	Percentage
Does not use any digital technologies	16	32.0
CAD/CAM Digital Design and Manufacturing System	13	26.0
CAD/CAM Digital Design and Manufacturing System, 3D Printing	14	28.0
CAD/CAM Digital Design and Manufacturing System, 3D Printing, Metal Printer	7	14.0
Total	50	100.0

The adoption of digital technologies varies among the surveyed technicians. A substantial 32% (n=16) reported not using any digital technologies. Among those who do, CAD/CAM Digital Design and Manufacturing Systems are the most commonly used (26%, n=13), followed closely by a combination of CAD/CAM and 3D Printing (28%, n=14). A smaller group (14%, n=7) utilizes a more comprehensive set of digital tools, including metal printers. This indicates a significant portion of the industry is still operating traditionally, while others are embracing various levels of digitalization.

Table 4 Impact of Digital Technologies on Work

Impact	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Increased efficiency and productivity	24	48.0	44.0	58.0
Increased efficiency and productivity, Changed the nature of required skills	2	4.0	2.0	60.0
Increased efficiency and productivity, Reduced need for labor	6	12.0	10.0	70.0
Increased efficiency and productivity, Reduced need for labor, Changed the nature of required skills	7	14.0	12.0	82.0
Increased efficiency and productivity, Had no significant impact	2	4.0	2.0	84.0
Changed the nature of required skills	2	4.0	2.0	86.0
Reduced need for labor	2	4.0	4.0	90.0
Had no significant impact	5	10.0	10.0	100.0
Total	50	100.0		

The most frequently cited impact of digital technologies on work is increased efficiency and productivity, reported by 48% (n=24) of respondents. This highlights a strong positive perception of digitalization's operational benefits. Combinations of impacts, such as increased efficiency and productivity coupled with a reduced need for labor (12%, n=6) or changed nature of required skills (4%, n=2), also feature prominently. A smaller segment (10%, n=5) indicated no significant impact, suggesting that the benefits are not universally experienced or recognized.

Table 5 Biggest Challenges in Adopting Digital Technologies

Challenge	Frequency	Percentage	Valid Percentage	Cumulative Percentage
High cost	22	44.0	44.0	50.0
High cost, Difficulty in maintenance and operation	4	8.0	2.0	52.0
High cost, Lack of proper training	8	16.0	16.0	68.0
High cost, Lack of proper training, Difficulty in maintenance and operation	3	6.0	6.0	74.0
Lack of proper training	12	24.0	24.0	98.0
Lack of proper training, Difficulty in maintenance and operation	1	2.0	2.0	100.0
Total	50	100.0		

The most significant barrier to adopting digital technologies is identified as high cost, cited by 44% (n=22) of the respondents. This is closely followed by the lack of proper training, reported by 24% (n=12). Combinations of these challenges, such as high cost coupled with lack of proper training (16%, n=8), further emphasize the dual financial and educational hurdles faced by dental technicians in Libya. This finding aligns with global observations regarding technology adoption in developing economies (Zandinejad *et al.,* 2025; Liao, P., & Budsabong 2024).

Table 6 Job Threat from Digital Technology

Response	Frequency	Percentage	Valid Percentage	Cumulative Percentage
To some extent	18	36.0	36.0	38.0
I don\'t know	5	10.0	8.0	46.0
No, because I am learning new skills	21	42.0	42.0	88.0
Yes, significantly	6	12.0	12.0	100.0
Total	50	100.0		

The perception of job threat due to digital technology is varied. A notable 42% (n=21) of respondents do not feel threatened, primarily because they are actively learning new skills. However, 36% (n=18) feel threatened to some extent, and 12% (n=6) feel significantly threatened. This suggests that while a proactive approach to skill development can mitigate perceived threats, a considerable portion of the workforce remains concerned about the implications of digitalization on their job security.

Table 7 Change in Number of Technicians After Digital Adoption

Response	Frequency	Percentage	Valid Percentage	Cumulative Percentage
The number increased due to the need for new skills	12	24.0	18.0	24.0
I don\'t know	13	26.0	26.0	50.0
No, the number is the same but tasks have changed	16	32.0	32.0	82.0
Yes, the number of technicians has been reduced due to automation	9	18.0	18.0	100.0
Total	50	100.0	100.0	

The impact of digital adoption on the number of technicians in laboratories shows a nuanced picture. The most common response (32%, n=16) indicates that the number of technicians remained constant, but their tasks evolved. 24% (n=12) reported an increase in technician numbers due to the demand for new skills, while 18% (n=9) experienced a reduction due to automation. This suggests that digitalization often leads to a transformation of roles rather than a simple reduction in workforce size, emphasizing the need for reskilling and upskilling initiatives.

Table 8 Change in Working Hours After Digital Adoption

Response	Frequency	Percentage	Valid Percentage	Cumulative Percentage
No significant difference	11	22.0	22.0	32.0
No, hours are the same but productivity increased	12	24.0	24.0	56.0
Yes, working hours decreased due to device efficiency	27	54.0	44.0	100.0
Total	50	100.0	100.0	

A majority of respondents (54%, n=27) reported a decrease in working hours due to the increased efficiency of digital devices. This highlights a significant positive impact on work-life balance and operational effectiveness. Another 24% (n=12) noted that while hours remained the same, productivity increased, further underscoring the efficiency gains. Only 22% (n=11) observed no significant difference, suggesting that for most, digital adoption has led to more optimized working conditions.

Table 9 Biggest Impact of Digitalization on Dental Technicians

Impact	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Improved accuracy and quality of restorations	12	24.0	22.0	24.0
Improved accuracy and quality of restorations, Reduced delivery time to the patient	9	18.0	18.0	42.0
Improved accuracy and quality of restorations, Reduced delivery time to the patient, Increased pressure to learn new skills	1	2.0	2.0	44.0
Reduced need for manual labor	9	18.0	18.0	62.0
Reduced need for manual labor, Improved accuracy and quality of restorations	1	2.0	2.0	64.0
Reduced need for manual labor, Improved accuracy and quality of restorations, Reduced delivery time to the patient	5	10.0	10.0	74.0
Reduced need for manual labor, Improved accuracy and quality of restorations, Reduced delivery time to the patient, Increased pressure to learn new skills	5	10.0	10.0	84.0
Reduced need for manual labor, Increased pressure to learn new skills	1	2.0	2.0	86.0
Reduced delivery time to the patient	6	12.0	12.0	98.0
Increased pressure to learn new skills	1	2.0	2.0	100.0
Total	50		100.0	

The most frequently perceived major impact of digitalization is the improved accuracy and quality of restorations (24%, n=12). This is a critical benefit in dental technology, directly affecting patient outcomes. Other significant impacts include reduced delivery time to the patient (18%, n=9) and reduced need for manual labor (18%, n=9). The data also indicates that while digitalization brings efficiency, it also introduces increased pressure to learn new skills, as seen in various combined impact categories. This highlights the dual nature of technological advancement: benefits in quality and speed, alongside demands for continuous learning.

Table 10 Training on CAD/CAM or 3D Printing Technologies

Response	Frequency	Percentage	Valid Percentage	Cumulative Percentage
No, but I would like to	18	36.0	34.0	36.0
No, and I\'m not interested	1	2.0	2.0	38.0
Yes, self-training	20	40.0	40.0	78.0
Yes, formal training	11	22.0	22.0	100.0
Total	50	100.0		

The data on training indicates a strong inclination towards self-training (40%, n=20) among dental technicians for CAD/CAM and 3D printing technologies. Formal training accounts for 22% (n=11). Significantly, 36% (n=18) expressed a desire for training even if they haven't received it yet, underscoring a high demand for structured learning opportunities. Only a small fraction (2%, n=1) is not interested in such training. This highlights a proactive workforce eager to adapt, but in need of more accessible and formal training pathways.

Table 11 Essential New Skills for Dental Technicians

Skill	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Digital data analysis	1	2.0	2.0	8.0
Operating 3D printers	2	4.0	4.0	12.0
CAD/CAM design	16	32.0	26.0	38.0
CAD/CAM design, Digital data analysis	1	2.0	2.0	40.0
CAD/CAM design, Operating 3D printers	16	32.0	32.0	72.0
CAD/CAM design, Operating 3D printers, Other (specify)	2	4.0	4.0	76.0
CAD/CAM design, Operating 3D printers, Digital data analysis	12	24.0	24.0	100.0
Total	50	100.0		

CAD/CAM design and operating 3D printers are overwhelmingly considered the most essential new skills, each cited by 32% (n=16) of respondents. A significant portion (24%, n=12) also views a combination of CAD/CAM design, operating 3D printers, and digital data analysis as crucial. This reinforces the shift towards digital proficiency as a core competency for modern dental technicians, moving beyond traditional manual skills.

Table 12 Evaluation of Training and Professional Development Opportunities in Libya

Evaluation	Frequency	Percentage	Valid Percentage	Cumulative Percent
Good	10	20.0	20.0	22.0
Weak	32	64.0	62.0	84.0
Non-existent	5	10.0	10.0	94.0
Excellent	3	6.0	6.0	100.0
Total	50	100.0		

The assessment of training and professional development opportunities in Libya reveals a critical gap. A vast majority of respondents rated these opportunities as weak (64%, n=32) or non-existent (10%, n=5). Only a small minority found them to be good (20%, n=10) or excellent (6%, n=3). This stark finding underscores the urgent need for improved and accessible training infrastructure to support the digital transformation of the dental technology sector in Libya.

Table 13 Future of Traditional Dental Laboratories in Libya

Opinion	Frequency	Percentage	Valid Percentage	Cumulative Percent
Will evolve to integrate new technologies	20	40.0	38.0	40.0
Will continue but with limited roles	17	34.0	34.0	74.0
Will become extinct due to technology	11	22.0	22.0	96.0
I don\'t know	2	4.0	4.0	100.0
Total	50	100.0	100.0	

Opinions on the future of traditional dental laboratories are divided, reflecting the uncertainty and transformative nature of digitalization. The largest group (40%, n=20) believes traditional labs will evolve by integrating new technologies, indicating a hopeful and adaptive outlook. However, a significant portion (34%, n=17) anticipates that traditional labs will continue but with limited roles, while 22% (n=11) fear their extinction due to technology. This highlights the perceived necessity for adaptation and the potential for disruption if traditional practices fail to embrace digital advancements.

Table 14 Policies Necessary to Support Dental Technicians During Digital Transformation

Policy	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Establishing specialized training centers	8	16.0	16.0	18.0
Providing loans to purchase digital devices	4	8.0	8.0	26.0
Providing loans to purchase digital devices, Establishing specialized training centers	2	4.0	4.0	30.0
Providing free/subsidized training courses	12	24.0	22.0	52.0
Providing free/subsidized training courses, Establishing specialized training centers	6	12.0	12.0	64.0
Providing free/subsidized training courses, providing loans to purchase digital devices	6	12.0	12.0	76.0
Providing free/subsidized training courses, providing loans to purchase digital devices, Establishing specialized training centers	12	24.0	24.0	100.0
Total	50	100.0		

The most frequently recommended policy to support dental technicians during digital transformation is providing free/subsidized training courses (24%, n=12). This is closely followed by a comprehensive approach that includes free/subsidized training, loans for digital devices, and establishing specialized training centers (24%, n=12). These findings strongly suggest that a multi-faceted policy framework, addressing both skill development and financial accessibility, is crucial for a successful transition. Establishing specialized training centers (16%, n=8) and providing loans for digital devices (8%, n=4) are also seen as important individual policy measures.

The perceived impacts of digital technologies are largely positive, with increased efficiency and productivity being the most frequently cited benefits. This is consistent with the widely recognized advantages of digital workflows in dentistry, which include improved accuracy, reduced manual labor, and faster turnaround times (Liao, P., & Budsabong, 2024; Abduo *et al.,* 2024). The reduction in working hours reported by a majority of technicians further underscores the efficiency gains brought about by digitalization, potentially leading to better work life balance and increased job satisfaction (Lo Russo *et al.,* 2020; Mussano *et al.,* 2023). However, the emergence of new skill requirements and the pressure to adapt also highlight the transformative nature of these technologies on job roles.

Conclusion

"The transition to digital dentistry in Libya is a double-edged sword for dental technicians. While CAD/CAM and 3D printing enhance precision and efficiency, they pose a significant threat to the job security of those relying solely on traditional methods. This study concludes that the risk of job loss is not caused by the technology itself, but by the digital gap and the lack of formal training. Consequently, the survival of dental technicians in the evolving Libyan market depends on their ability to transition from manual crafters to digital specialists. This shift requires urgent institutional support to provide the necessary training and infrastructure.

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