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Digital technology implementation in prosthodontics postgraduate programs in Saudi Arabia: a multi-institutional survey of program directors

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Abstract

Objective To assess the current status of digital technology (DT) implementation in prosthodontics post-graduate (PG) programs in Saudi Arabian dental institutions.

Methodology A 19-item survey was created using Google forms and the link was emailed to the 29 prosthodontics PG program directors (advanced clinical training and joint program) in Saudi Arabia. The questionnaire contained five Sect. 1) didactic training and DT usage in PG preclinical, clinical and laboratory training, 2) incorporation of DT in PG program, 3) utilization of DT and the types of cases treated by PG students during their course, 4) information on the faculties involved in prosthodontics PG education, and 5) potential challenges encountered and program directors' satisfaction of the PG program. Descriptive statistics was used to present the frequencies and proportions, and Chi square inferential test was used to compare the participants' response based on the type of PG programs ($\alpha = 0.05$).

Results Only 28 program directors responded to the survey, yielding a 95.5% response rate. Among the program directors, 24 (85.7%) and 4 (14.3%) directors supervised the advanced clinical training and joint programs, respectively. Among the DT, CAD/CAM was the most used technology (50–80%), followed by intra-oral scanning (28–96%). Digital technology implementation was largely limited by lack of resources or equipment (67%), cost (53%) and scarcity of PG teaching staff (46%). A significant difference was observed between the programs regarding the mandatory use of DT for their cases ($p = 0.03$).

Conclusions This multi-institutional survey of program directors revealed that DT is continuously implemented in the last few years. Saudi dental institutions must prioritize implementing and utilizing DT in PG training to graduate competent prosthodontists in this fast-paced digital era. While DT is pivotal in dental education, its implementation is limited in many institutions due to resources or equipment, cost, and lack of trained faculty.

Keywords Computer-aided design, Computer-aided manufacturing, Dental education, Digital technology, Prosthodontics

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Introduction

The utilization of digital applications and technological advancements in medicine and dentistry has expanded over the years [1]. Digital technology (DT) is not only becoming more widely available, but they also deliver better and more controllable outcome while significantly reducing treatment time [2, 3]. The use of DT in dentistry has seen tremendous progress in the past decade, upending every aspect of clinical and laboratory workflow, from patient diagnosis to prosthetic design to surgical preparation and to the exchange and storage of patient data [4]. Digital technology has made it easier for clinicians, patients, dental technologists, and other healthcare providers who are involved in the care of patients to improve the clarity of communication, in addition, to implementing better quality control measures [5–10].

Prosthodontics is a skill-sensitive dental speciality pertaining to the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues by using biocompatible substitutes [11]. Since DT are used for most prosthodontic procedures, digitalization is now an integral part of modern-day prosthodontics [12]. Digital technologies such as digital imaging, digital impression, intraoral scanners, computer-aided design and manufacturing (CAD/CAM), and 3D- printing have improved the prosthodontic workflow and changed the aspects of modern day dental practice [4, 13, 14]. That said, with DT permeating every aspect of dentistry, prosthodontics has much to offer and plenty to gain [15].

As for any digital technology, high-quality training of clinicians is necessary for successful implementation in routine patient care [16, 17]. Dental institutions should produce graduates who are well-trained and aware of the latest technological advancement in their specialities. Thus, implementation of DT and workflows is indispensable in the contemporary education of dental students. In different studies, a positive perspective was found of undergraduate (UG) students on the implementation of DT in the preclinical and clinical curriculum [18, 19]. However, the integration of DT education into the undergraduate curricula was barely due to the continued emphasis on conventional teaching methods, which include traditional laboratory procedures like waxing, casting, finishing, and tooth preparation exercises on a phantom head (simulation unit). Moreover, the difficulty was in using new DT, such as the so-called computer-aided learning (CAL), without ignoring the development of manual skills, which are still crucial for dental care. The lack of equipment and shortage of competent faculty also showed further obstacles [20, 21].

Postgraduate (PG) students are expected to adopt DT more readily than UG students and are eager to learn the available advanced technologies during their clinical training so as to obtain maximum benefit from the program. They are also expected to have minimum technical barriers in adopting digital resources compared to UG students [22]. Two recent studies assessed DT implementation in removable prosthodontics courses; the proportion of PG programs that process cases using DT was higher than the UG programs. Similar to previous UG studies, these studies also showed that UG and PG programs are still largely limited by a lack of funds, resources, time, and faculty members. The authors concluded that more research be conducted to support the continued incorporation of DT into dental education [4, 23].

Saudi Arabia's healthcare system is being reformed by a healthcare transformation program aligned with Vision 2030 to be more comprehensive, efficient, and integrated than ever. It also prioritizes meeting international standards, enhancing healthcare quality, promoting e-health services and digital solutions. Despite the growing interest in DT in prosthodontics, there is clear gap in the literature regarding the current status of DT implementation in prosthodontics PG curricula among the dental institutions in Saudi Arabia. The future prosthodontists are considered to be an integral part of Saudi Arabia's healthcare system and their DT knowledge and training are determined by the existing academic exposure. By evaluating the current status of DT in prosthodontic PG programs, we are able to project implementation trends while understanding the challenges that impede dental educational institutions from implementing these technologies. Program directors are considered valid indicators of improvements and changes in PG prosthodontic education and training.

Therefore, this study aimed to assess the current implementation of DT in prosthodontics PG programs in Saudi Arabian dental institutions according to program directors. Specifically, the study assessed students' interest in DT education, level of faculty training in DT training, and any potential challenges to its implementation in the PG curricula and program satisfaction according to program directors.

Methodology

The Institutional Review Board at the College of Dentistry, Prince Sattam Bin Abdulaziz University approved this cross-sectional study (Approval #. SCBR-093-2023). The target group for the survey was the 29 directors of prosthodontics PG programs in Saudi Arabia, either joint academic (Master or Doctor of Science in dentistry with advanced clinical training) or advanced

clinical training (Saudi Board). Hence, this survey followed a voluntary response sampling approach. The program directors' filling out and submitting the survey served as informed consent and allowed the collected data to be used in this study. The names of the dental institutions were recorded solely for research purposes, and all the survey responses were kept confidential.

A cross-sectional questionnaire was framed in English using practice-based knowledge and pre-validated questions adapted from previous studies [4, 18, 24–26]. The questionnaire contained 19 questions assessing the current status of DT implementation in the prosthodontics PG program curricula. The first question was related to the type of program and the remaining 18 questions were divided into five sections. Section 1 questions focused on didactic training and DTs used in PG preclinical, clinical and laboratory training. Section 2 contained questions regarding the incorporation of DT in PG program. Section 3 contained questions to retrieve information regarding the mandatory use of DT, % and type of DT used by PG students in direct and indirect workflow. Section 4 aimed to obtain information about the faculties involved in PG student training, and finally Sect. 5 contained questions regarding the potential challenges to the implementation of DT in the PG curricula, and evaluating the overall satisfaction of the program directors about the digital workflow in their prosthodontics PG programs.

The content validity of the questionnaire was performed by a panel of five professors involved in joint academic or advanced clinical training in prosthodontic PG education at the College of Dentistry, King Saud University. The feedback from the review panel suggested refinement and modification to questions related to PG student's information and faculties involved with PG training (Sects. 4 and 5, respectively), which were considered and applied. The reliability of the questionnaire was performed by test-retest method on 10 respondents [27]. The intra class correlation (ICC) coefficient was between 0.71 and 1.00, suggesting moderate to excellent reliability of the questionnaire.

The online questionnaire was uploaded to Google Forms (Google LLC, Menlo Park, CA, USA), and the link was emailed to all the 29 directors of PG prosthodontic programs in Saudi Arabia. A cover letter stating the aim of the study and confidentiality statement was included with the questionnaire. The email addresses of the program directors were obtained from the Saudi Commission for Health Specialties or from the university website. To increase the response rate, a follow-up reminder email was sent to all program directors two weeks after the initial email, seeking their participation to complete the survey. The 19-item survey was designed to be completed in approximately 6–8 min.

In most of these questions, the participants were allowed to select multiple responses for their responses. The responses to the survey were collected and tabulated on an electronic spreadsheet (Excel 2016; Microsoft, Redmond, WA, United States) for data processing. Data analysis was performed using SPSS statistical software for windows (version 22.0; IBM Corp., Armonk, NY, USA). Descriptive analysis was used to summarize the attributes of the obtained data and presented as frequency and proportions. Chi Square inferential statistics test was used to compare the distribution of participants' responses based on the type of prosthodontics PG program and the presence of certified faculty in the program. The level of significance was set at $p < 0.05$.

Results

Only 28 program directors responded to the survey, yielding a 95.5% response rate. Among the PG programs in prosthodontics, 24 (85.7%) program directors supervised the advanced clinical training program, while 4 (14.3%) supervised the joint program.

Section 1: didactic training and DTs used in PG preclinical, clinical and laboratory training

Table 1 presents the program directors' responses to survey items 2, 3, 4 and 5. Two program directors responded that they program did not provide didactic teaching on DT in the PG program.

Among the directors who provided didactic training in PG program stated that intraoral scanning (85.7%), CAD/CAM (84%), implant planning (68%), and digital smile analysis (64%) were used in didactic training.

Only 19 directors confirmed that they PG program taught DT in pre-clinical laboratory, and accordingly, CAD/CAM (59%), intraoral scanning (53.6%), digital smile analysis (32%) and implant planning (25%) was commonly used DT.

In the clinics, CAD/CAM (85%), implant planning (71%), intraoral scanning (67.9%), and digital smile analysis (60.7%) were commonly used DT.

However, in the laboratory, the use of DT was justified with the laboratory works and the most used DT were CAD/CAM (87%), additive technology (50%), extra-oral scanning (39%) and implant planning (35%).

Overall, it can be seen that the DT were commonly used in clinics compared to pre-clinical laboratory and dental laboratory.

Table 1 Distribution of participants' responses to survey item 2, 3, 4 and 5

Questions	Responses	*n*	%
Q2. Does your postgraduate program provide didactic teaching on digital technology? If yes, which digital technology is taught? (Select all that apply)	No	2	7.1%
	Intra-oral scanning	24	85.7%
	Extra-oral scanning	9	32.1%
	Computer aided designing (CAD)	23	82.1%
	Computer aided milling (CAM)	24	85.7%
	Additive technology	11	39.3%
	Digital smile analysis	18	64.3%
	Implant planning software	19	67.9%
Q3. Does your postgraduate program teach digital technology in the preclinical laboratory? If yes, which digital technology is taught? (Select all that apply)	No	9	32.1%
	Intra-oral scanning	15	53.6%
	Extra-oral scanning	7	25.0%
	Computer aided designing (CAD)	18	64.3%
	Computer aided milling (CAM)	15	53.6%
	Additive technology	5	17.9%
	Digital smile analysis	9	32.1%
	Implant planning software	7	25.0%
Q4. Does your postgraduate program use digital technology in the clinics? If yes, which digital technology is used? (Select all that apply)	No	2	7.1%
	Intra-oral scanning	19	67.9%
	Extra-oral scanning	10	35.7%
	Computer aided designing (CAD)	23	82.1%
	Computer aided milling (CAM)	25	89.3%
	Additive technology	9	32.1%
	Digital smile analysis	17	60.7%
	Implant planning software	20	71.4%
Q5. Does your laboratory use digital technology? If yes, which digital technology is used? (Select all that apply)	No	2	7.1%
	Intra-oral scanning	8	28.6%
	Extra-oral scanning	11	39.3%
	Computer aided designing (CAD)	23	82.1%
	Computer aided milling (CAM)	26	92.9%
	Additive technology	12	42.9%
	Digital smile analysis	6	21.4%
	Implant planning software	10	35.7%

Section 2: information regarding when, how and duration of incorporating DT in PG program

Regarding the year of incorporating DT during the PG program, about 19 (67.9%) of the participants responded as 1st year, followed by 6 (21.4%) in 2nd year and 1(3.6%) in the final or 4th year.

Digital technology education was incorporated as a basic course (39%) and by lectures incorporated in restorative or prosthodontic courses/ crash courses/ workshops by corporate trainers (50%). Only 11.7% of participants confirmed that DT was an elective course in PG education.

When asked about the number of years that DT is being taught in PG programs at their institutions, maximum (20) of the directors said it was from 1–5 years', 2 was between 6 and 10 years' experience, 1 was > 10 years', and 4 of was < 1-year (See Table 2). So, this data suggests that DT is being introduced or taught in the past few years.

Section 3: information regarding the mandatory use of DT, % and type of DT used by PG students in direct and indirect workflow

Table 3 presents the program directors' responses to survey items 9, 10, and 11. Regarding the mandatory use of DT by the PG students at their institutions, 50% of the directors responded that it was not mandatory while 50% replied "Yes".

Among the directors who replied "Yes," further responded that CAD/CAM (39.3%), intra-oral scanning (35.7%), implant planning software (35.7%), and digital

Table 2 Distribution of participants' responses to survey item 6, 7 and 8

Questions	Responses	*n*	%
Q6. In which year of the postgraduate program is digital technology incorporated?	Not applicable	2	7.1%
	1st year	19	67.9%
	2nd year	6	21.4%
	3rd year	0	0%
	4th year	1	3.6%
Q7. How do you incorporate digital technology education into your postgraduate program?	Not applicable	2	7.1%
	Basic course	11	39.3%
	Lectures incorporated in a restorative/prosthodontic course	14	50.0%
	Crash course	14	50.0%
	Elective course	3	10.7%
	Workshop by corporate trainers	14	50.0%
Q8. How long have you been teaching digital technology in your program?	Not applicable	1	3.6%
	< 1 year	4	14.3%
	1–5 years	20	71.4%
	6–10 years	2	7.1%
	> 10 years	1	3.6%

Table 3 Distribution of participants' responses to survey item 9, 10 and 11

Questions	Responses	*n*	%
Q9. Are your postgraduate students mandatorily required to use digital technology with their cases? If yes, which digital technology are used?	No	14	50.0%
	Intra-oral scanning	10	35.7%
	Extra-oral scanning	3	10.7%
	Computer aided designing (CAD)	11	39.3%
	Computer aided milling (CAM)	11	39.3%
	Additive technology	3	10.7%
	Digital smile analysis	8	28.6%
	Implant planning software	10	35.7%
Q10. Are your postgraduate students interested in digital technology education and implementation? If yes, which digital technology are they interested in?	No	3	10.7%
	Intra-oral scanning	23	82.1%
	Extra-oral scanning	13	46.4%
	Computer aided designing (CAD)	22	78.6%
	Computer aided milling (CAM)	22	78.6%
	Additive technology	16	57.1%
	Digital smile analysis	21	75.0%
	Implant planning software	22	78.6%
Q11. What percentage of cases are treated using digital technology in your postgraduate program?	< 10%	9	32.1%
	11–50%	12	42.9%
	51–75%	2	7.1%
	> 76%	5	17.9%

smile analysis (28.6%) were the mandatorily used technology. The least used DT were 3D printing and extra oral scanning (10.7%).

Regarding the PG students interest in DT, three directors responded that their students were not interested in DT. The remaining 25 (10.1%) responded that their students were interested in DT, especially the intra-oral scanning (82.1%), CAD/CAM and implant planning software (78.6%), digital smile analysis (75.0%), 3D printing (57.1%) and extraoral scanning (46.4%).

Regarding the percentage of cases treated using DT, 12 (42.9%) participants responded 11–50% cases, 9 (32.1%)

participants responded < 10% cases, 5 (17.9%) participants responded > 76% cases and 2 (7.1%) participants responded 51–75% cases.

The participant's responses to the type of cases treated in direct and indirect digital workflow using DT is presented in Fig. 1. In the direct digital workflow, most participants ($n = 23$;82.1%) responded that implant-supported prostheses and computer-guided implant stents were treated using DT at their institutes, followed by single crowns ($n = 19$;67.9%), fixed partial dentures ($n = 18$;64.3%) and inlays/onlays ($n = 13$;64.3%). A few participants responded that removable partial and complete dentures ($n = 4$;14.3%) and occlusal appliances ($n = 3$; 10.7%) were also fabricated using DT.

In the indirect digital workflow, most participants ($n = 20$;71.4%) responded that implant-supported prostheses followed by single crowns and fixed partial dentures ($n = 19$;67.9%) and computer-guided implant stents ($n = 18$; 64.3%) were treated using DT.

Section 4: information on the faculties involved in prosthodontics PG education

The majority of the directors ($n = 17$; 60.7%) responded that their students were trained by PG faculties, 3 (10.7%) responded that it was the corporate trainers, and 7 (25.0%) responded that it was both PG faculties and corporate trainers (Q14; Fig. 2).

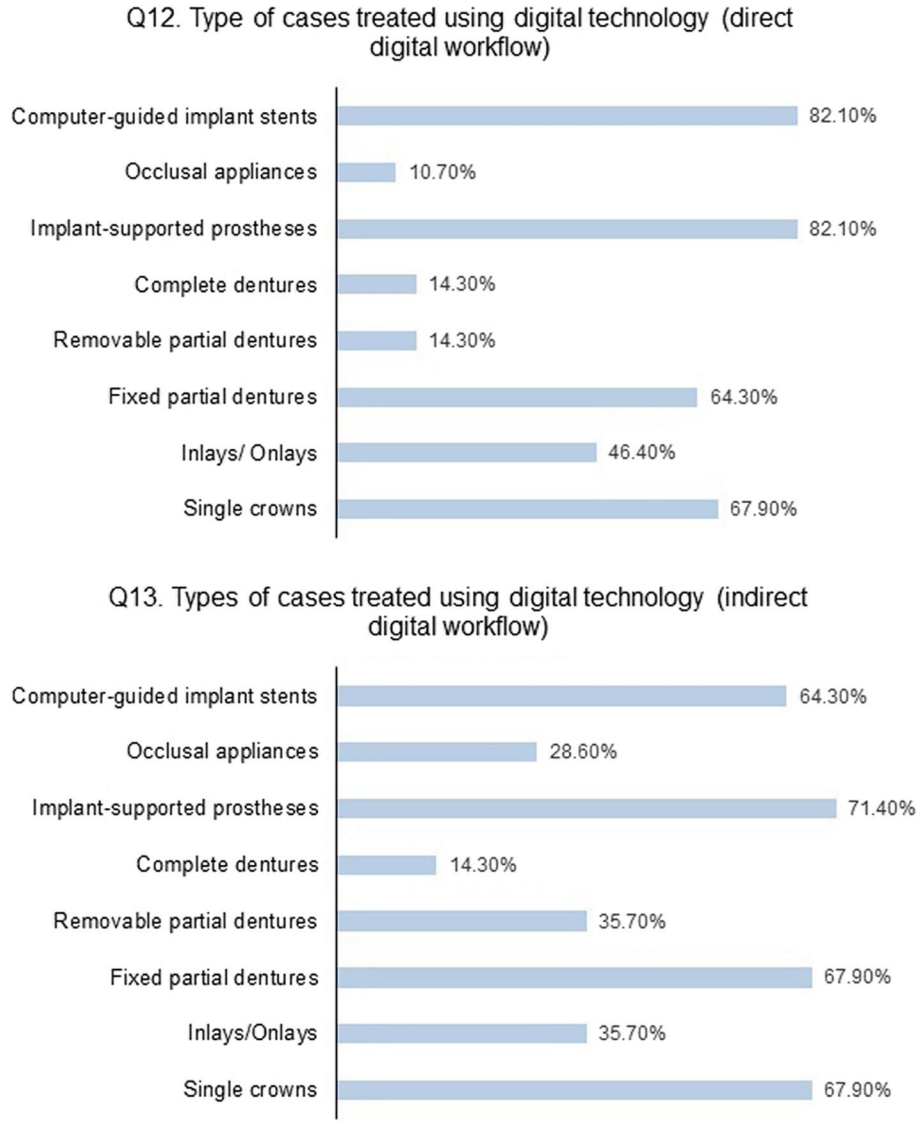

Fig. 1 Bar graph presenting the participants' responses to survey items 12 and 13

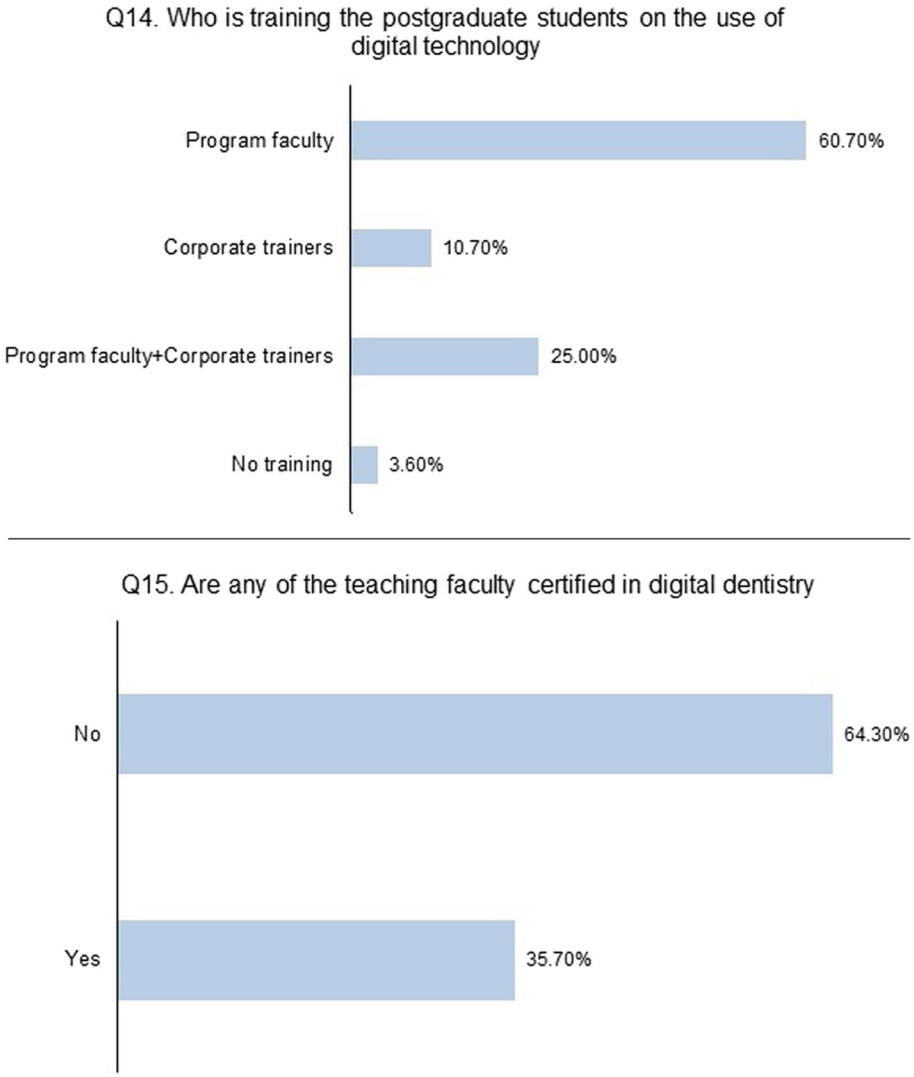

Fig. 2 Bar graph presenting the participants' responses to survey items 14 and 15

Among the participants, 18 (64.3%) responded that their faculties did not hold any certification in digital dentistry, while 10 (35.7%) responded that their faculties were certified in digital dentistry (Q15; Fig. 2).

Regarding training of the faculties in DT training, 71.4% of the participants responded that it was through self-learning, 64.3% responded that they were trained through workshops by corporates and 46.4% responded that their faculties were trained during their PG program (Q16; Fig. 3).

When asked about the percentage of PG faculty trained in DT, 12 program directors responded that it was less than 10%, 11 responded that it was 11–50%, 3 responded that it was 51–75%, and 2 participants responded that it was more than 76% (Q17; Fig. 3).

Section 5: potential challenges encountered in implementing DT and program directors' satisfaction of the PG program

Concerning the challenges or difficulties faced with the implementation of DT in prosthodontics PG program, 3 (10.7%) directors faced no problems. On the contrary, 19 (67.9%) participants responded lack of resources or equipment, 15 (53.6%) responded that it was the cost, 13 (46.4%) responded that it was lack of faculty and staff availability or training, 4 (14.3%) responded that it was lack of time available to update the curriculum, and 2 (7.1%) responded that it was students' lack of interest in using DT (Q18; Fig. 4).

Regarding the program directors' satisfaction of the digital work at their institution, 7 (25.0%) of them were extremely satisfied, 9 (32.1%) were somewhat satisfied, 7

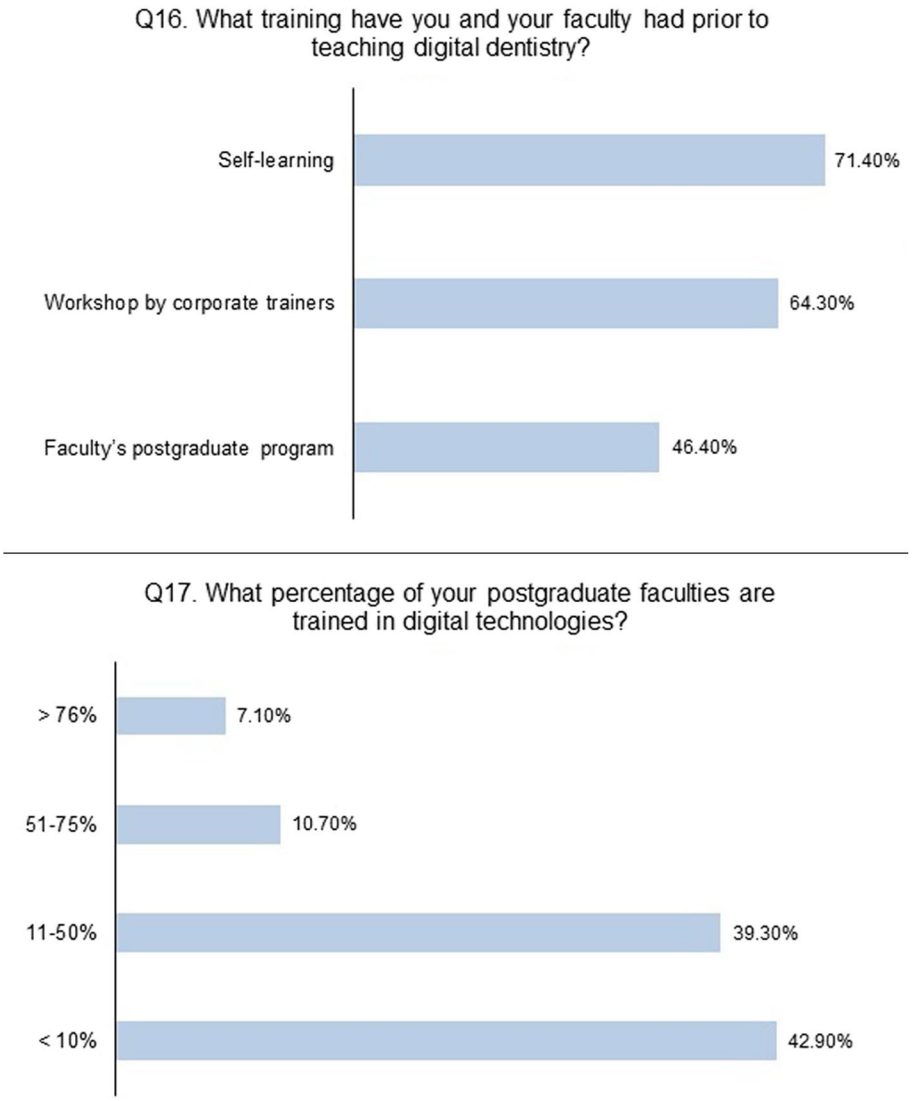

Fig. 3 Bar graph presenting the participants' responses to survey items 16 and 17

(25.0%) were neither satisfied nor dissatisfied, 4 (14.3%) were somewhat dissatisfied, and 1 (3.6%) participant showed extreme dissatisfaction (Q19; Fig. 4). Overall, 16 of the directors were satisfied, 7 were neutral and 5 were dissatisfied.

Comparison of responses between the two programs

A chi-square inferential statistics test was used to compare the distribution of subjects' responses based on the type of PG program in prosthodontics. The outcome demonstrated a statistically significant difference ($p=0.04$) for the use of additive technology between the joint program (75.0%) and the advanced clinical training program (25.0%). Similarly, a significant difference was observed between the programs regarding the mandatory use of DT for their cases ($p=0.03$) and occlusal appliance fabrication in the indirect digital workflow ($p=0.03$). Digital technology in advanced clinical training programs was incorporated as a basic course. In contrast, it was not considered a basic course in the joint programs, and the difference showed borderline significance ($p=0.08$).

Discussion

The decision to specialize is an important phase in a practising dentist's career. Prosthodontic training aims to provide dental practitioners in an exceptional speciality, who work with complex dental situations such as dental rehabilitations and overseeing refractory patients in a fast-paced dental world [28]. Nowadays, the digitalization trend is pervasive in daily life and dentistry is

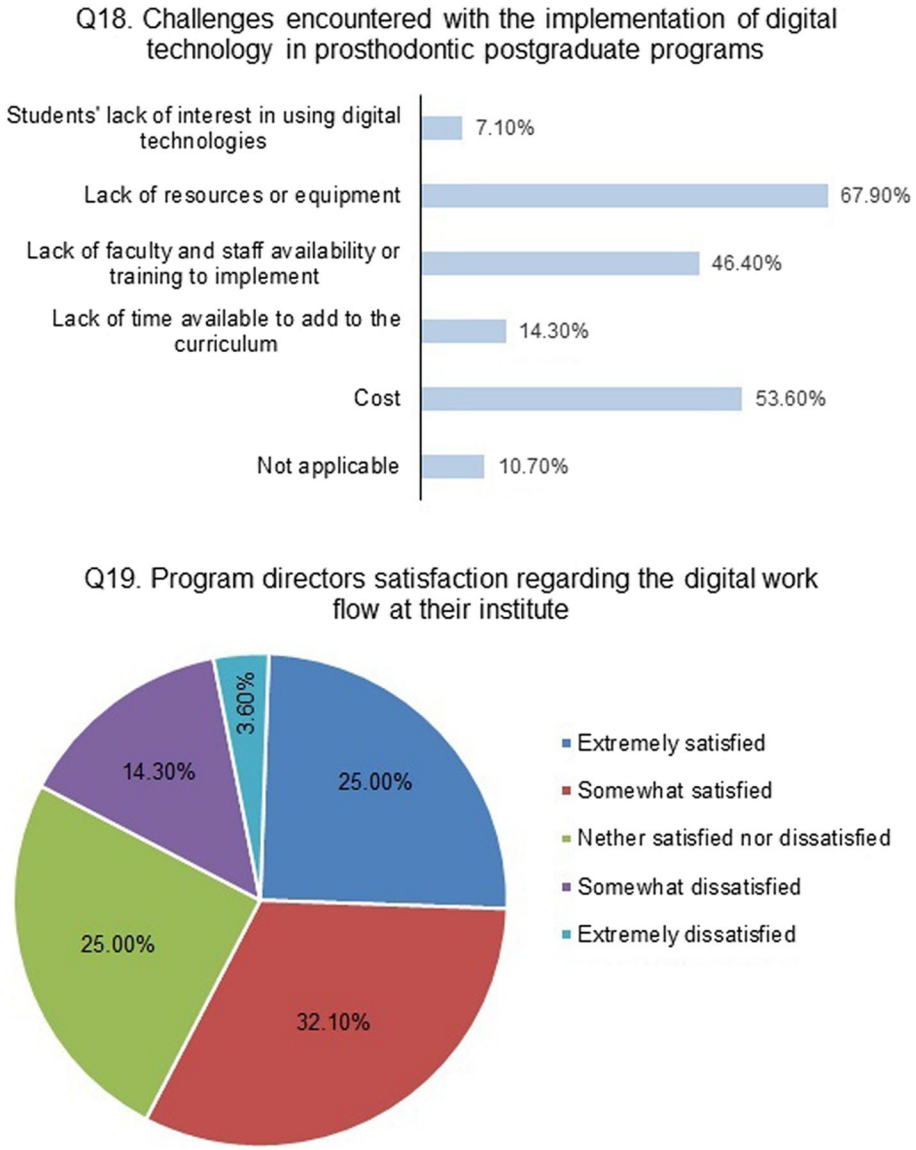

Fig. 4 Bar graph presenting the participants' responses to survey items 18 and 19

no exception [29]. Digital technology implementation in dentistry has numerous advantages, including better patient satisfaction, fewer processing errors, simplified laboratory procedures, enhanced communication with dental technologists, and more effective teaching and learning experience [4]. Specifically, the DT implementation in prosthodontics has four benefits: improved communication, improved treatment quality, archiving of patient data and the most crucial is the patient experience. Dental specialists are unlikely to comprehend the latest technologies if DT and novel materials are not introduced into the curricula. Furthermore, they are unable to make informed decisions regarding the most appropriate techniques, technology, or materials in the future [30]. Therefore, it is necessary to include DT education or training in the PG program curricula.

The current study assessed the status of DT implementation in prosthodontics PG programs in Saudi Arabian dental institutions from the prosthodontics PG program directors' perspective. The outcome of the study finds significance because of the two main questions. Firstly, "Where do we stand in this rapidly progressing technological world as related to the implementation of the DT into prosthodontics PG programs" and secondly, "Are we adequately resourceful to implement advanced DT in prosthodontics PG programs to improve

precision, effectiveness, and general quality of healthcare procedures."

Among the 28 directors, 26 responded that they provided didactic teaching on DT. It is now evident that not all prosthodontic PG programs provide didactic teaching in DT. In prosthodontic programs, PG students are trained in multiple practical settings: preclinical, clinic and laboratory [31]. This study showed that only some settings within the dental institutes that support PG clinical and laboratory work provide training in DT. Among the digital technologies applied, CAD/CAM and intraoral scanning were adopted more readily than other technologies. Compared to other settings, the use of DT was predominant in clinical settings.

The increased application of CAD/CAM technology could be attributed to their various advantages, including enhanced efficiency, precision, and skill in favouring interactive teaching [4, 8]. Based on the outcome of this study, the majority of participants reported that their PG students used CAD/CAM technology routinely in their preclinical dental laboratory, clinics and dental laboratories during their course. This outcome is supported by a recent study in Saudi Arabia [32], which concluded that CAD/CAM technology is a core part of Saudi prosthodontists and is being used to fabricate more restorations than the conventional technique. Al-Ibrahim et al. [25]in their study also showed that Saudi dentists had high satisfaction and a positive attitude toward using CAD/CAM technology in clinical practice.

Intraoral scanners are devices for taking direct digital impressions, and the therapeutic application of the digital impression is well established. This approach saves time over the traditional impression technique in mixing, setting, sanitizing, or casting [33, 34]. Furthermore, making digital impressions is eco-friendly since it reduces the harmful waste that conventional impressions in dental offices produce. The simplicity of documentation is a significant advantage. Patient records can be digitally retained on a hard drive or in the cloud and retrieved whenever necessary [33, 34].

Most participants responded that DT education was introduced in their PG program's 1st year (67.9%), which is a positive step. The students' exposure to DT during the 1st year gives them enough time to understand, practice and implement the technology in their clinical practice before they graduate. One of the concerning aspects of this survey response was that most of the DT education or training was obtained through lectures, crash courses and corporate training rather than a basic course, especially with the joint program. Training through basic courses complemented by corporate training or lectures could provide a deeper and broader understanding of the subject. Most dental institutions in Saudi Arabia have been offering prosthodontic PG education for the past 30 years. However, most participants (71.4%) responded that DT was being implemented within the last 1–5 years, and 14.3% responded that it was less than a year. This confirms that DT is newly introduced to PG programs and has been continually implemented in the last few years in Saudi dental institutions.

Notably, 50% of the participants responded that DT was not mandatory for treatment of patient cases in their programs. However, most participants responded that their students were interested in DT education and implementation. The students were very interested in CAD/CAM, intraoral scanning, digital smile analysis and implant planning software. Digital smile design and analysis allow a clinician to construct and project a new smile design by simulating and visualizing the result of the suggested treatment. A digitally developed design involves patient involvement in the design process of their self-smile design, resulting in smile design customization based on individual needs [7, 35]. Using implant planning software, the implants can be visualized and planned most effectively to support the desired ultimate prosthetic result [36]. Computer-guided implant surgery has a low rate of experience among the clinicians in Saudi Arabia. Ashy [37], in her study assessed the clinicians' attitude in Saudi Arabia towards using different implant surgery and found that most clinicians find it to be an appealing approach. The survey outcome was based on the response from faculty members and Saudi board residents in implantology, oral surgery, periodontics, and prosthodontics from two dental institutions in Riyadh and Jeddah, respectively. In another study from Saudi Arabia [38], Albugami et al. evaluated the education and training received by dentists who practiced implant therapy in Riyadh city using a self-administered questionnaire. The authors found that majority (43.2%) of the practicing dentists received formal education regarding implant placement during their PG training. This is followed by participation in implant courses or seminars (30.7%), undergraduate training (13%), fellowship or board training (9.9%), and doctoral training (8.3%). However, the majority of the dental practitioner interviewed in this study were expatriates.

Most participants (64%) responded that their program faculty trains PG students in DT, followed by combined faculty and corporate training (25%). This study also showed that most PG faculties need to be certified in digital dentistry. The program faculties according to this study received their formal training in digital dentistry either through the faculty's PG program, self-learning or corporate training. This explains the impact of corporate companies and their training in implementing DT in PG programs. Rapid technological advancement by

dental manufacturers is another driving force behind the implementation of DT in dentistry. Many large laboratory groups and dental companies invest significant resources in education and even hire individuals whose primary job is training. This is a classic "win-win" scenario: the industry would gain access to the youngest target group of potential prospects, and the dental institution would be equipped with the latest technologies. During such collaboration, the colleges must remain impartial by providing a range of products from different companies. If not, they may unintentionally influence dental students and steer them toward a particular technological approach [39].

Establishing and maintaining the educational environment for digital dentistry is not without current and prospective challenges. Furthermore, the prosthodontic discipline is difficult to teach and requires many resources. Before implementing DT, institutions must comprehend the challenges and create a strong foundation and infrastructure [40]. In the current study, lack of resources or equipment, cost and lack of staff or faculty were considered as the barriers to the successful implementation of DT in prosthodontic PG program. The transitional phases of financial limits, faculty shortages, and time to add to the curriculum are always associated with implementing new technology.

Dental institutions need to manage the financial aspects of incorporating numerous digital equipment and technologies besides personal motivation. Ensuring a significant number of the latest devices and technology are available across different department settings is a very challenging task. Dental institutions could deal with financial problems by collaborating with dental manufacturers, receiving research grants, or generous donations from alums. A survey of dental school deans in the US showed that new clinical technologies and cost are the most significant barriers facing dental schools' financial strategies [41].

Faculty shortages still need to be dealt in dental education, and ongoing efforts to foster a better awareness of the wide depth of academic life are vital. As a result, appropriate faculty development in DT is crucial. Dental institutions should produce graduates who are well-informed about latest technological advancement in dentistry [4]. Future rankings of the most prestigious dental schools will take into consideration both the faculty's level of innovation and the digital infrastructure of the dental school [39].

Dental education revolutionized by DT has a substantial impact on prosthodontist. Dental practices and institutions are significantly investing in digital infrastructure. With new technologies each day, a new framework for training dentists has been developed by utilizing these digital tools. This has shown that DT in prosthodontics favourably influences expectations of the industry, patients, technicians, clinicians, and educators more quickly and probably more than expected [15].

Although the current study is considered the first to assess the current status of the DT implementation in prosthodontics PG programs in Saudi Arabia, the strength and limitation of the study are worth-mentioning. This survey provides a strong foundation for evaluating the current status of DT implementation in PG prosthodontic education using a reliable and validated questionnaire. These data could be used to establish future curriculum guidelines for PG prosthodontic education, internal outcome measures and to assure quality in the PG prosthodontic curriculum. Another strength is the comprehensive assessment of the parameters that could limit the implementation of DT in PG programs. Regarding the limitations, the study followed a voluntary response sampling method. The outcome is based on the responses perceived by the program director and is devoid of responses from other faculty members or the PG students. The perception of students and other faculty members may have different perception and interest regarding DT utilization in PG program. The responses were not categorised based on the regions or by government or private institutions and the DTs categories used in the questionnaire were limited to those commonly used. Future studies with larger sample size that comprising other prosthodontic faculties and PG students should be conducted. The categorisation of responses based on the regions and government or private institutions would provide a more comprehensive understanding of the current status of DT implementation. It would also be interesting to explore the strategies to address the limitations identified in implementing DT in PG programs. Finally, it is recommended to do a follow-up survey to monitor how these dental institutions will accelerate the implementation of DT in their curricula in line with Saudi vision 2030.

Conclusion

Digital technology integration into routine clinical practice has aided clinicians deliver the most advanced treatment by reducing treatment costs and patient visits. Saudi dental institutions must prioritize implementing and utilizing DT in PG training to graduate competent prosthodontists in this fast-paced digital era. Although DT is pivotal in dental education, its implementation is limited in many institutions due to resources or equipment, cost, and lack of trained faculty. Further research must be conducted to explore strategies to address these barriers and also to monitor the acceleration and implementation of DT in prosthodontic PG programs.

CADCAM removable prosthodontics in dental curricula, we can predict the trends in implementation and understand the barriers that prevent schools from adopting these technologies.

Abbreviations

3D	Three dimensional
CAD/CAM	Computer-aided design/Computer-aided manufacturing
CAL	Computer-aided learning
DT	Digital technology
PG	Post-graduates
SPSS	Statistical Package for the Social Sciences
UG	Under graduates

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Author contributions
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Data availability
All data that support the findings of this study are included in the current manuscript.

Declarations

Ethics approval and consent to participate
The study was approved by the Institutional Review Board at the College of Dentistry, Prince Sattam Bin Abdulaziz University (Approval #. SCBR-093-2023). The program directors' filling out and submitting the survey served as informed consent and allowed the data collected to be used in this study.

Consent for publication
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Competing interests
The authors declare no competing interests.

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References

1. Alsufyani N, Alnamlah S, Mutaieb S, Alageel R, AlQarni M, Bukhari A, et al. Virtual reality simulation of panoramic radiographic anatomy for dental students. J Dent Educ. 2023;87(8):1200–9.
2. Cervino G, Fiorillo L, Arzukanyan A, Spagnuolo G, Cicciù M. Dental Restorative Digital Workflow: digital smile design from aesthetic to function. Dent J 2019, 7(2).
3. van Noort R. The future of dental devices is digital. Dent Mater. 2012;28(1):3–12.
4. Ishida Y, Kuwajima Y, Kobayashi T, Yonezawa Y, Asack D, Nagai M et al. Current Implementation of Digital Dentistry for Removable Prosthodontics in US Dental Schools. Int J Dent. 2022, 2022:7331185.
5. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J. 2008;204(9):505–11.
6. Blatz MB, Chiche G, Bahat O, Roblee R, Coachman C, Heymann HO. Evolution of aesthetic Dentistry. J Dent Res. 2019;98(12):1294–304.
7. Coachman C, Calamita MA, Coachman FG, Coachman RG, Sesma N. Facially generated and cephalometric guided 3D digital design for complete mouth implant rehabilitation: a clinical report. J Prosthet Dent. 2017;117(5):577–86.
8. Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am. 2011;55(3):559–70. ix.
9. Güth JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clin Oral Investig. 2013;17(4):1201–8.
10. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health. 2014;14(1):10.
11. The Glossary of Prosthodontic Terms. J Prosthet Dent. 2005;94(1):10–92.
12. Zhou Y. How does Digital Technology shape the future of Prosthodontics? J Ind Prosthodont Soc. 2018;18(Suppl 1):S6.
13. Durgesh B, Alshehri A, Alsadon O, Alaqeel S, Alageel O, Alsarani M, et al. Coffee Staining and simulated brushing Induced Color changes and Surface Roughness of 3D-Printed Orthodontic Retainer Material. Polymers. 2023;15(9):e2164.
14. Jahangiri L, Akiva G, Lakhia S, Turkyilmaz I. Understanding the complexities of digital dentistry integration in high-volume dental institutions. Br Dent J. 2020;229(3):166–8.
15. Lyndon F, Mark E. Digital White Paper: the current impact of digital technology in prosthodontics. Digital Dentistry resources. USA: Amercian College of Prosthodontists Education Foundation; 2017.
16. Gratton DG, Kwon SR, Blanchette D, Aquilino SA. Impact of Digital Tooth Preparation Evaluation Technology on Preclinical Dental Students' Technical and self-evaluation skills. J Dent Educ. 2016;80(1):91–9.
17. Rekow D. Digital Dentistry: a Comprehensive Reference and Preview of the future. 1st ed. Batavia: Quintessence Pub Co.; 2018.
18. Schlenz MA, Michel K, Wegner K, Schmidt A, Rehmann P, Wöstmann B. Undergraduate dental students' perspective on the implementation of digital dentistry in the preclinical curriculum: a questionnaire survey. BMC Oral Health. 2020;20(1):78.
19. Sheba M, Comnick C, Elkerdani T, Ashida S, Zeng E, Marchini L. Students' perceptions and attitudes about digital dental technology is associated with their intention to use it. J Dent Educ. 2021;85(8):1427–34.
20. Callan RS, Haywood VB, Cooper JR, Furness AR, Looney SW. The validity of using E4D compare's % comparison to assess Crown preparations in Preclinical Dental Education. J Dent Educ. 2015;79(12):1445–51.
21. Wolgin M, Grabowski S, Elhadad S, Frank W, Kielbassa AM. Comparison of a prepcheck-supported self-assessment concept with conventional faculty supervision in a pre-clinical simulation environment. Eur J Dent Educ. 2018;22(3):e522–9.
22. Lam WY-H, Mak KC-K, Maghami E, Molinero-Mourelle P. Dental students' preference and perception on intraoral scanning and impression making. BMC Med Edu. 2021;21(1):501.
23. Fernandez MA, Nimmo A, Behar-Horenstein LS. Digital Denture Fabrication in pre- and postdoctoral education: a Survey of U.S. Dental Schools. J Prosthodont. 2016;25(1):83–90.
24. Alfallaj HA, Afrashtehfar KI, Asiri AK, Almasoud FS, Alnaqa GH, Al-Angari NS. The Status of Digital Dental Technology Implementation in the Saudi Dental Schools' curriculum: a National Cross-sectional Survey for Healthcare Digitization. Int J Environ Res Public Health. 2023;20(1):321.
25. Al-Ibrahim I, Alshammari F, Alanazi S, Madfa A. The attitude of Saudi dentists towards CAD/CAM in Restorative Dentistry. Open Dent J 2023, 17.
26. Eugenia P, Bradley S, William E, Steven R. Moving Forward in Digital Dentistry. Volume 54. Cranbury, NJ, USA: MJH life sciences; 2020.
27. Saunders M, Lewis P, Thornhill A, Bristow A. In: Saunders M, Lewis P, Thornhill A, editors. Research methods for Business Students Chap. 4: understanding research philosophy and approaches to theory development. Harlow: Pearson; 2019. pp. 128–71.
28. Dudley J. An 8-year retrospective study of fixed prosthodontics clinical unit completions in a postgraduate prosthodontics program. Health Sci Rep. 2023;6(6):e1331.

29. Joda T, Zarone F, Ferrari M. The complete digital workflow in fixed prosthodontics: a systematic review. BMC Oral Health. 2017;17(1):124.
30. Chatham C, Spencer MH, Wood DJ, Johnson A. The introduction of digital dental technology into BDS curricula. Br Dent J. 2014;217(11):639–42.
31. Lagreca GF, Kang K. Meaningful integration of educational technology in postgraduate programs: Problem, solution, and results. J Dent Educ. 2021;85(Suppl 1):990–3.
32. Aboukoura K, Karunakaran S, Tulli M, Zubedi T, Gandhi C, Siddiqi NA. Knowledge of CAD/ CAM or Conventional Ceramic Material restorations in Prosthodontics: a qualitative research. Saudi J Oral Dent Res. 2020;5(4):219–22.
33. Judit B, Alexandra C, Viktoria V, Ivett R, Péter H. Intraoral scans for CAD/CAM application. Stomatology Edu J. 2018;5(2):110–7.
34. Suzuki Y, Harada N, Watanabe KI, Maruo R, Shimpo H, Ohkubo C. Clinical application of an intraoral scanner and CAD/CAM system for a Kennedy class I partially edentulous patient. J Oral Sci. 2022;64(1):109–11.
35. Thomas P, Krishnamoorthi D, Mohan J, Raju R, Rajajayam S, Venkatesan S. Digit Smile Des J Pharm Bioallied Sci. 2022;14(Suppl 1):S43–49.
36. Ludlow M, Renne W. Digital Workflow in Implant Dentistry. Curr Oral Health Rep. 2017;4(2):131–5.
37. Ashy LM. Clinicians' attitude toward computer-guided Implant surgery Approach: Survey in Saudi Arabia. Pragmat Obs Res. 2021;12:1–8.
38. Albugami R, Smith S, Hassan M, Almas K. Trends in implant dentistry: Implant systems, complications and barriers in Riyadh, Saudi Arabia. Dent Med Probl. 2019;56:223–30.
39. Zitzmann NU, Matthisson L, Ohla H, Joda T. Digital Undergraduate Education in Dentistry: a systematic review. Int J Environ Res Public Health. 2020;17(9):3269.
40. Brownstein SA, Murad A, Hunt RJ. Implementation of new technologies in U.S. dental school curricula. J Dent Educ. 2015;79(3):259–64.
41. McAllister DE, Garrison GE, Feldman CA, Anderson EL, Cook BJ, Valachovic RW. U.S. Dental School Deans' perceptions of the rising cost of Dental Education and Borrowing pressures on Dental students: report of Survey results. J Dent Educ. 2015;79(6):719–27.

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