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A Survey On The Knowledge, Attitude And Perception Of Dental Professionals Regarding The Role Of Artificial Intelligence And Its Applications In Dentistry: A Cross Sectional Study

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Abstract -- Background and objective:

Artificial intelligence is gradually mooting its way contemporaneously with the present day evolution in the field of dentistry. Given that AI may have a profound effect on practitioners both now and in the future, it is important to comprehend the fundamental idea, underlying theory, and anticipated uses of AI. Thus, the purpose of this study was to evaluate dental professionals' attitude, knowledge, and perception of artificial intelligence and its applications in dentistry.

Materials and methods:

This was a cross-sectional questionnaire-based survey comprising of 28 questions that was circulated through google forms to dental professionals for assessing the cognizance of the individuals towards artificial intelligence, its vantage points and drawbacks and their outlook regarding the inception of artificial intelligence in dentistry .

Results:

Out of the 219 responses received, 206 participants found the Application of AI in dentistry amazing. Predominantly (91.8%) responded that significant advances can result with advent of AI. Majority believed that AI can assist in decision making, diagnosing and predictive analysis. Majority (84.9%) agreed that virtual reality and augmented reality will help in treatment processes and 190 participants believed it will enhance the dental curriculum.

Conclusion:

According to the study's findings, dental professionals and students are aware of artificial intelligence (AI) and its potential uses. The results of this survey prompted us to identify critical shortcomings that need to be addressed, highlighting the importance of incorporating, developing, and enhancing AI training in dental schools.
Keywords : Artificial intelligence (AI), Dentistry, CADCAM, Treatment ,Survey.

INTRODUCTION:

Artificial Intelligence (AI) originated in the mid-20th century, when pioneers like Alan Turing and John McCarthy began exploring the concept of machines that could simulate human intelligence. Early attempts were centered on problem-solving and symbolic reasoning. The introduction of machine learning, particularly deep learning, revolutionized the field, enabling systems to learn from vast amounts of data. Today, AI applications span numerous industries, from healthcare to finance, and continue to evolve, pushing the boundaries of what machines can achieve. The journey of AI is marked by breakthroughs in natural language processing, computer vision, and robotics, promising an exciting future with endless possibilities.

AI has made significant inroads into dentistry, transforming various aspects of the field. From diagnostic imaging to treatment planning, AI algorithms analyze radiographs and patient data to identify dental issues with remarkable accuracy.

Dentists are frequently utilizing computer software to make decisions. Meanwhile, software designed for dental purposes is becoming increasingly sophisticated, precise, and reliable. Research on artificial intelligence have permeated every field of dentistry.[1,2]

AI improves the adeptness at arriving at a solid Radiologic diagnosis [3] like detecting carious lesions, [4,5] Temporomandibular joint disorders, [6] oral carcinoma with its prognosis, survival rate and metastasis, [7,8] periapical, radiolucent, and cystic lesions.[9-12] Also to detect periodontitis and its types,[13] periodontal bone loss,[14] interpreting cephalograms and predicting pre and post treatment changes in orthodontics,[13] crown designing and fabrication,[15] shade matching[16] and debonding prediction of CAD/CAM restorations.[17]

However, the discussion regarding sensitive information, privacy protection, and ethical issues continues to persist in various areas such as research, public, political, and industrial sectors. Policymakers and medical professionals need legal clarification due to unclear guidelines and uncertainty about responsibility for machine errors.[18]

Therefore, this survey was conducted to evaluate and comprehend the knowledge, attitude, and perspective on the utilization of artificial intelligence among dental professionals, while also gathering their thoughts on the future developments and progress of artificial intelligence in the field of dentistry.

MATERIALS AND METHODS :

This study employed a cross-sectional questionnaire design to evaluate the knowledge,

attitude and perception of dental professionals regarding artificial intelligence and how it can be potentially utilized in the field of dentistry based on their academic and clinical knowledge.

A cross-sectional questionnaire-based study was conducted in the Department of Prosthodontics at Sri Venkateshwaraa Dental College, Pondicherry, India, between august 2024 to November 2024. The Institutional Ethical Committee and Institutional Research Board approval was obtained (SVDC/IEC-CER/2023-24/17 and SVDC/IRB/2024/1203/PG SHORT STUDY/02).
Dental professionals including faculties of academic institutions, private practitioners postgraduate and undergraduate dental students (third year, final year) who consented to participate in this study were included. First and second year undergraduate students and non-dental professionals were excluded.
The data was gathered by sending the link of the online form via emails and WhatsApp to all the study participants Along with the questionnaire, informed consent was obtained from these participants via Google forms. Any problems that arose during the questionnaire's completion were promptly fixed by the researcher throughout the investigation.
The sample size was estimated to be n = 183 (with 10% attrition) based on the previous study[18] and using the formula, $N=4\times PQ/D^2$
Where, N is sample size, 'P' stands for highest prevalence which was 13 for pilot study, Q=100-P and 'D' stands for acceptable error or lowest prevalence of 5%. Therefore, the sample size calculated was 183. The study included a total of 219 respondents. The pilot testing of the questionnaire included 27 respondents which comprised of undergraduates, postgraduates, faculties and private practitioners.

A customized questionnaire was designed that comprised of 35 questions, in which 2 were open ended and 33 were close ended. The questionnaire was divided into 4 parts which included demographic details (Q no.1-7), Knowledge based questions (Q no. 8-11), Attitude based questions (Q no. 12-21), Perception based questions (Q no. 22-35).
With a Content Validity Index score (CVIs) of 0.60, the questionnaire was verified for Face validity (question relevance specific to the survey issue) and Content validity (reliability of the options offered) by the faculty from the Department of Prosthodontics, Sri Venkateshwaraa Dental College, Pondicherry along with subject expert.

The questionnaire's internal consistency and reliability, as determined by the pilot study, showed that it was reliable, with an internal consistency score of 0.8 for Cronbach's alpha. The participants have to respond to every question. The pilot testing of the questionnaire included 27 respondents which comprised of undergraduates, postgraduates and private practitioners.

STATISTICAL ANALYSIS:
Each participant's unique response was compiled onto an MS Excel file. Statistical analysis was

performed using SPSS software version 20.0. Descriptive statistics was used. With a significance level of p-value <0.05, the Chi-square test was used to see whether there was any significant correlation between the questionnaire items and the respondent.

RESULTS:

		Number	**Percentage**
Gender	Males	163	74.4
	Females	56	25.6
Qualification	Undergraduate	127	58
	CRRI	57	26
	Postgraduate	17	7.8
	Dental practitioner/graduate	18	8.2
Area of Practice	Urban	70	32
	Rural	31	14.2
	Not Practicing	118	53.9
Years of Experience	Less than 5 years	63	28.8
	6 to 15 years	5	2.3
	> 15 years	1	0.5
	Not Applicable	150	68.5

Table 1: Demographic characteristics of study participants

Majority of participants 163 (74.4%) were males and 56 (25.6%) participants were females. About 127 (58%) participants were undergraduate students, 57 (26%) participants were CRRIs, 17 (7.8%) participants were postgraduate students, and 18 (8.2%) participants were dental practitioners.

	Yes		**No**	
	Number	**Percentage**	**Number**	**Percentage**
Are you familiar with dental equipment powered by AI?	146	66.7	73	33.3
Are you aware that there are websites that use AI?	107	48.9	112	51.1
Can significant advances result in Dentistry with the advent of Artificial intelligence?	201	91.8	18	8.2
Will AI eventually be able to replace dentists in the future?	102	46.6	117	53.4
Is it amazing to find the Application of AI in dentistry?	206	94.1	13	5.9
Can AI diagnose and detect illness better than humans?	75	34.2	144	65.8
Would you prefer following AI's dental care plan if it differs	75	34.2	144	65.8

from yours?				
Will the risk-benefit ratio be better for patients with AI choice of treatment?	112	51.1	161	48.9
Will the risk-benefit ratio be better for patients with conventional treatment planning?	161	73.5	58	26.5

Table 2: Study participant's responses towards various items in questionnaires

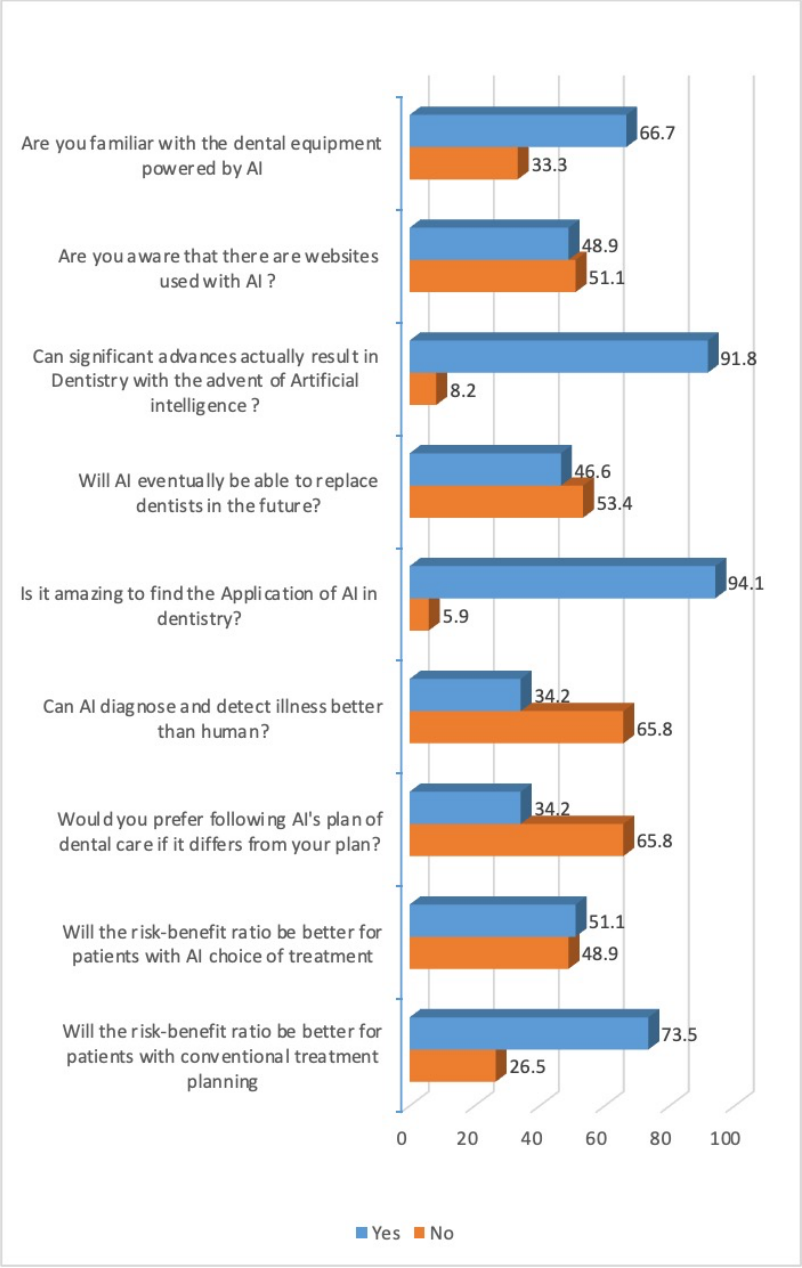

Figure 1: Study participant's responses towards various items in questionnaires

About 201 (91.8%) participants believe that AI can make significant advances in dentistry. About 206 (94.1%) participants find AI to be an amazing addition to dentistry. However, 161 (73.5%) participants believe that the risk-benefit ratio will be better if treatment is planned conventionally.

	Number	Percentage
RVG	117	20.14
CAD-CAM	98	16.87
Digital IOPA	88	15.15
CBCT	79	13.60
Electronic Apex locator	86	14.80
Intra-oral scanner	76	13.08
Digital dental records	37	6.37
Total	581	100

Table 3: Distribution of participants who were familiar with dental equipment powered by AI

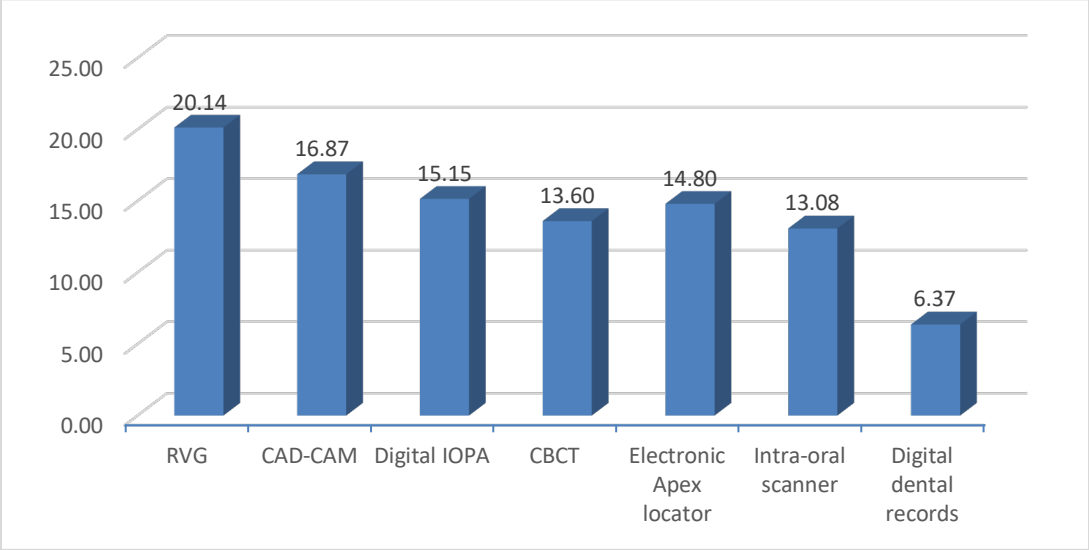

Figure 2: Distribution of participants who were familiar with dental equipment powered by AI

	Number	Percentage
Making Treatment Decisions	61	8.79
Making a diagnosis	84	12.10
Interpreting complicated radiograph scans	129	18.59
Direct treatment (including robots for surgery	60	8.65

Treating TMJ dysfunction	60	8.65
Telerobotic-assisted drilling	60	8.65
Arch-wire Bending	60	8.65
Crown Preparation	60	8.65
Haptic root canal treatment	60	8.65
Teeth cleaning mouthpiece for handicaps	60	8.65
Total	694	100

Table 4: Study participant's responses towards the field/area of dentistry benefitting from AI

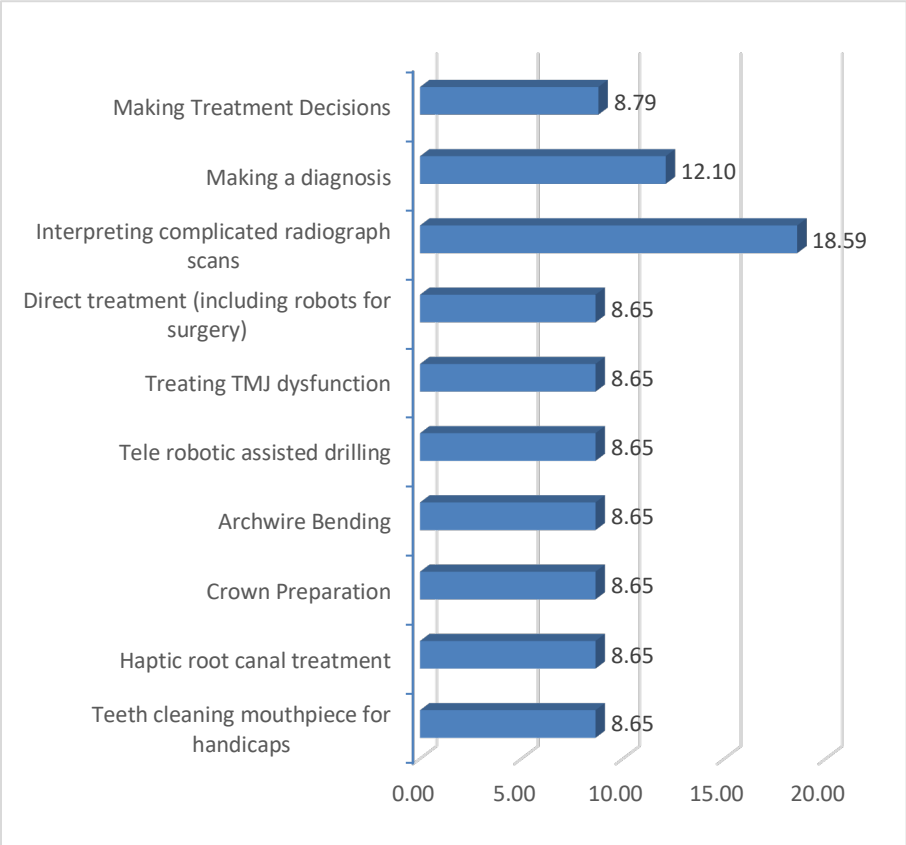

Figure 3: Study participant's responses towards the field/area of dentistry benefitting from AI

It was found that about 18.59% felt that AI could assist in interpreting complicated radiographic scans, while 12.1% felt that AI could assist in making a diagnosis.

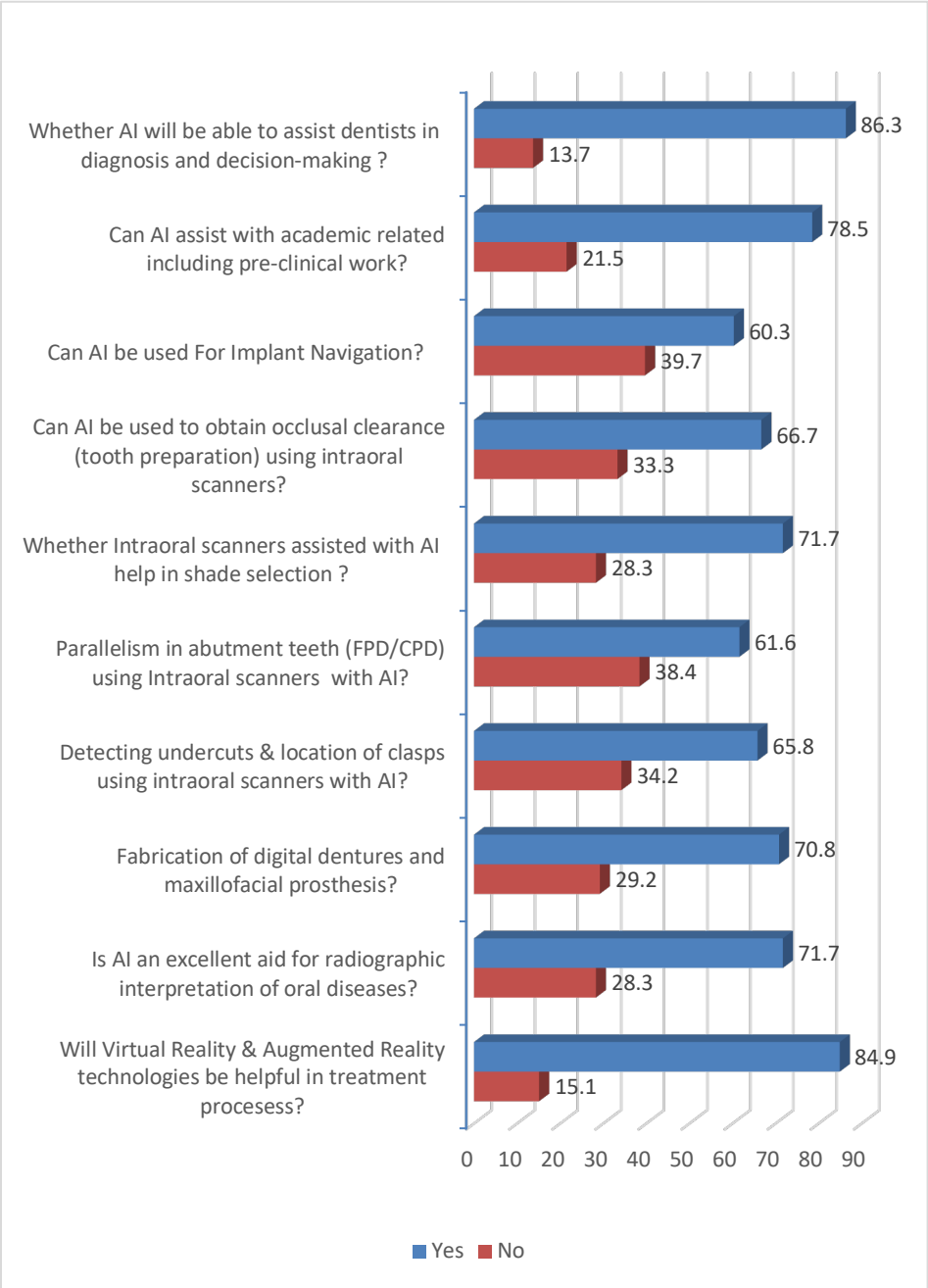

Figure 4: Study participant's responses towards various items in questionnaires

It was found that about 86.3% of participants believed that AI would be able to assist dentists in diagnosis and making decisions, and 84.9% believed that virtual reality & augmented reality would be helpful in various stages of treatment planning. About 78.5% believed that AI could assist in academic-related work including pre-clinical work.

	Yes		No	
	Number	**Percentage**	**Number**	**Percentage**
AI will be able to assist dentists in diagnosis and decision-making.	189	86.3	30	13.7
Can AI assist with academic-related related including pre-clinical work?	172	78.5	47	21.5
Can AI be used For Implant Navigation?	132	60.3	87	39.7
Can AI be used to obtain occlusal clearance (tooth preparation) using intraoral scanners?	146	66.7	73	33.3
Whether Intraoral scanners assisted with AI help in shade selection?	157	71.7	62	28.3
Parallelism in abutment teeth (FPD/CPD) using Intraoral scanners with AI?	135	61.6	84	38.4
Detecting undercuts & location of clasps using intraoral scanners with AI?	144	65.8	75	34.2
Fabrication of digital dentures and maxillofacial prostheses?	155	70.8	64	29.2
Is AI an excellent aid for the radiographic interpretation of oral diseases?	157	71.7	62	28.3
Will Virtual Reality & Augmented Reality technologies be helpful in treatment processes?	186	84.9	33	15.1

Table 5: Study participant's responses towards various items in questionnaires

	Yes		No	
	Number	**Percentage**	**Number**	**Percentage**
Dental Implant placement & complex surgeries by Robotic systems can revolutionize treatment outcomes.	164	74.9	55	25.1
Can AI be used as an adjunct to forensic dentistry?	175	79.9	44	20.1
Can AI-assisted Surgical Procedures can reduce clinic time, work quality, and number of visits?	170	77.6	49	22.4
Can AI be used to enhance the dental curriculum?	190	86.8	29	13.2
Will future advances in AI in dentistry will impact creativity?	202	92.2	17	7.8
Will the use of AI in dental and medical fields can go against ethical norms?	154	70.3	65	29.7

Table 6: Study participant's responses towards future applications of AI in dentistry

About 202 (92.2%) participants believed that AI in dentistry would have an impact on creativity, and 190 (86.8%) participants believed that AI could be used to enhance dental curriculum. In addition, 175 (79.9%) believed that AI can be used as an adjunct to forensic dentistry and 170 (77.6%) felt that AI-assisted procedures can reduce clinic time, improve quality, and reduce the number of patient visits.

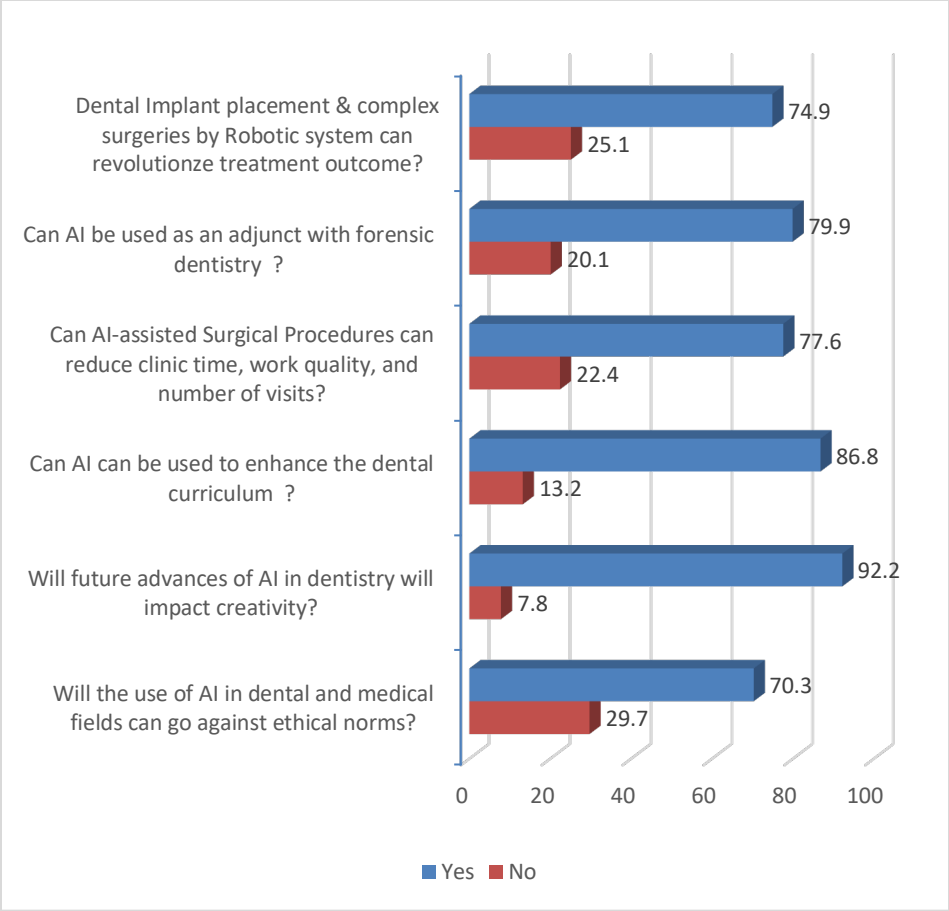

Figure 5: Study participant's responses towards future applications of AI in dentistry

	Males (N = 163)	**Females (N = 56)**	**P value**
Can AI be used For Implant Navigation?	90 (55.2)	42 (75)	P = 0.01*
Dental Implant placement & complex surgeries by Robotic systems can revolutionize treatment outcomes.	129 (79.7)	35 (62.5)	P = 0.013*
Can AI-assisted Surgical Procedures can reduce clinic time, work quality, and number of visits?	132 (81)	38 (67.9)	P = 0.04*
Will future advances in AI in dentistry will impact creativity?	154 (94.5)	48 (85.7)	P = 0.03*

Statistically significant at *p < 0.05 and **P < 0.01 using the Chi-square test

Table 7: Distribution of responses from the questionnaire according to gender (only significant responses)

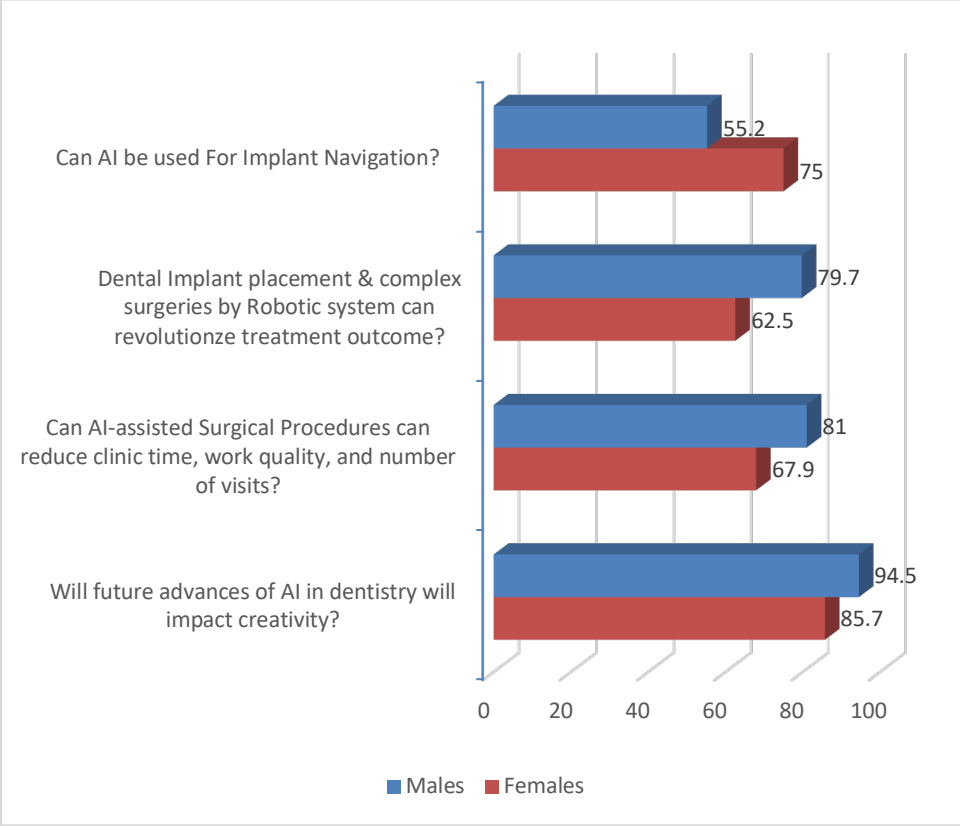

Figure 6: Distribution of significant responses from the questionnaire according to gender

	Under-graduates	**CRRI**	**Post-graduates**	**Dental graduates or practitioners**	**P value**
	N = 127	N = 57	N = 17	N = 18	
Is AI an excellent aid for the radiographic interpretation of oral diseases?	87 (68.5)	48 (84.2)	13 (76.5)	9 (50)	P = 0.024 *
Can AI be used as an adjunct to forensic dentistry?	102 (80.3)	50 (87.7)	9 (52.9)	14 (77.8)	P = 0.019 *
Will the use of AI in dental and medical fields can go against ethical norms?	87 (68.5)	48 (84.	12 (70.6)	7 (38.9)	P = 0.003

		2)			**

Statistically significant at *p < 0.05 and **P < 0.01 using the Chi-square test

Table 8: Distribution of responses from the questionnaire according to qualification (only significant responses)

It was found that a significant majority of CRRIs followed by postgraduates felt that AI can be an excellent aid for the interpretation of radiographs for oral diseases. (P = 0.024). In addition, a significant majority of CRRIs followed by undergraduate students believed that AI can be a useful adjunct to forensic dentistry. (P = 0.019). Finally, a significant majority of CRRIs followed by post-graduate students felt that the use if AI can be against ethical norms in dentistry and the medical field. (P = 0.003).

DISCUSSION:

In a time when technological support plays a critical role, it is imperative that we not only possess knowledge but also investigate the potential applications of technology in the dentistry area. When combined with dental professionals' expertise, artificial intelligence can enhance diagnostic, prognosis, and treatment results.

Undergraduate and graduate students should be taught the fundamentals of artificial intelligence in order for them to receive sufficient relevant and evidence-based information in the coming years.[20] Islam et al. have proposed that dentistry institutions adopt AI curricula using Bolman and Deal's Reframing Organizations as an infrastructure paradigm.[21] Similarly in this study 86.8% of the participants believed AI could be used to enhance dental curriculum. About 78.5% believed that AI could assist in academic-related work including pre-clinical work.

In this survey about 91.8% of the participants believed that AI can make significant advances in dentistry and about 206 (94.1%) participants find AI to be an amazing addition to dentistry. In a study conducted by Singh N et al, they have concluded that 52.3% of students said that incorporating AI would undoubtedly result in significant advancements in dentistry, there was dispute over whether or not it would totally replace practitioners.[20] Divya Tondon et al.[22] emphasized in their study that artificial intelligence cannot take the position of dental surgeons. This may be due to the fact that various dental treatments entail sensory perception as well as the maneuverability of dentists.[20] One possible explanation could be that effective therapy of oral illness requires patient discussions to foster empathy, confidence, and trust.

Also in our survey 73.5% participants believe that the risk-benefit ratio will be better if treatment is planned conventionally. In addition, 65.8% participants believe that AI cannot diagnose & detect illness better than humans, and a similar number of participants would not prefer following AI's plan of dental care if it differs from their plan.

Furthermore, the majority of people (62.8%) were aware of how artificial intelligence functions. On the other hand, there was nearly an equal distribution of knowledge and ignorance on the use of AI in dentistry was stated in the study by Singh N et al [20]. In our study about 66.7% participants were familiar with dental equipment powered by AI, as shown by numerous studies in the literature, participants

underlined the need for dentists to be taught about the fundamentals of artificial intelligence.[23,24]
By linking data that would otherwise be challenging to gather and compare, AI will continue to help clinicians make decisions. This is especially true as time goes on.[25] Besides the support in diagnostics, it will enhance efficiency and accuracy and will act as a 'definitive diagnostic, prognostic as well as treatment planning tool'.[20,25] Various studies proposed different models for detecting caries, diagnosing oral pathological lesions, accurate positioning of dental implants and utilizing data in forensic dentistry.[26,27,28] Similarly in our survey many(86.3%) the of participants believed that AI would be able to assist dentists in diagnosis and making decisions, and 84.9% believed that virtual reality & augmented reality would be helpful in various stages of treatment planning. About 71.7% felt that AI could assist in shade selection and would be able to radiographically interpret oral diseases like dental caries, periodontitis, and so on. It was found that a significant majority of CRRIs followed by postgraduates felt that AI can be an excellent aid for the interpretation of radiographs for oral diseases. (P = 0.024). In addition, a significant majority of CRRIs followed by undergraduate students believed that AI can be a useful adjunct to forensic dentistry. (P = 0.019). This was in concordance to studies by Awawdeh et al[29], Khanagar et al [30] and Yüzbasolu et al[31] that stated 41.6%, 58.4% and 67.6% people felt that AI can be advantageous in the field of forensic dentistry, respectively.
In our survey predominantly (70.3%), the participants believed that there is a possibility for AI in the medical and dental fields to go against ethical norms. (P = 0.003). It can be due to the use of AI often involves collecting and analyzing large amounts of patient data, which can pose risks to privacy if not handled securely. Biases in training data can be passed down to AI systems. If the training data does not represent diverse populations, AI may lead to misdiagnoses or inappropriate treatment recommendations for underrepresented groups. Determining responsibility in case of an error is complex. If an AI system makes a mistake, it can be unclear whether the dentist, the AI developer, or the institution is liable.
In accordance with our study, dental professionals especially dental students believe that AI can help enhance the dental curriculum, aid in Better learning, provide more efficient workflow, customized treatment programs, better diagnostics, and predictive analytics.
As mentioned in previous published works, a number of participants underlined the importance of incorporating fundamental operating principles and the possible use of AI in the future into their curricula. This can only be because of the aforementioned presumption as well as the practical challenges of applying AI to everyday work situations as opposed to educating, which is theoretically feasible.[12]
Moreover, this study provides a foundation for additional quantitative research on this subject. To be more precise, future research might concentrate on the effectiveness and caliber of the educational initiatives and policies that have been put in place to show how AI models have affected dentistry practices.

LIMITATIONS:

A more comprehensive sample size comprising individuals from a range of educational establishments ought to be employed, in conjunction with accurate and dependable sample classification predicated on gender and qualification. The sample size was not typical of all dentists. The gender distribution was unbalanced in relation to the topic being addressed. Adding open-ended questions and questions from the viewpoint of an AI specialist to the questionnaire might let participants share their favorable opinions about this rapidly developing technology.

CONCLUSION:

Most participants thought artificial intelligence (AI) would be useful in dentistry and were aware of its advantages. The study discovered that improved technical resources in clinics and postgraduate and undergraduate professional training programs may assist mitigate future obstacles to the use of artificial intelligence in dentistry.

This is essential to correct misconceptions and encourage professionals to engage in this field.

Acknowledgements

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Conflicts of interest

The authors declare that there are no conflicts of interests.

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This is a self-funded research that did not receive any external funding.

Ethical Approval

The Institutional Ethical Committee and Institutional Research Board approval was obtained (SVDC/IEC-CER/2023-24/17 and SVDC/IRB/2024/1203/PG SHORT STUDY/02).

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Figure Legends :

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REFERENCES:

1. Schleyer TK, Thyvalikakath TP, Spallek H, Torres-Urquidy MH, Hernandez P, Yuhaniak J. Clinical computing in general dentistry. J Am Med Inform Assoc. (2006) 13(3):344–52. doi: 10.1197/jamia.M1990
2. Chae YM, Yoo KB, Kim ES, Chae H. The adoption of electronic medical records and decision support systems in Korea. Healthc Inform Res. (2011) 17(3):172–7. doi: 10.4258/hir.2011.17.3.172
3. Van Leeuwen KG, de Rooij M, Schalekamp S, van Ginneken B, Rutten MJCM. How does artificial intelligence in radiology improve efficiency and health outcomes? Pediatr Radiol 2021 1–7.
4. Lee J-H, Kim D-H, Jeong S-N, et al. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent 2018;77:106–111.

5. Cantu AG, Gehrung S, Krois J, Chaurasia A, Rossi JG, Gaudin R, Elhennawy K, Schwendicke F. Detecting caries lesions of different radiographic extension on bitewings using deep learning. J Dent 2020;100:103425
6. Bas B, Ozgonenel O, Ozden B, Bekcioglu B, Bulut E, Kurt M. Use of artificial neural network in differentiation of subgroups of temporomandibular internal derangements: a preliminary study. J Oral Maxillofac Surg. 2012;70:51–59.
7. Lu C, Lewis JS, Dupont WD, Plummber WD, Janowczyk A, Madabhushi A. An oral cavity squamous cell carcinoma quantitative histomorphometric-based image classifier of nuclear morphology can risk stratify patients for disease-specific survival. Mod Pathol 2017;30:1655–1665.
8. Ariji Y, Fukuda M, Kise Y, et al. Contrast-enhanced computed tomography image assessment of cervical lymph node metastasis in patients with oral cancer by using a deep learning system of artificial intelligence. Oral Surg Oral Med Oral Pathol Oral Radiol 2019;127:458–463.
9. Ekert T, Krois J, Meinhold L, et al. Deep learning for the radiographic detection of apical lesions. J Endod 2019;45:917– 922.e5.
10. Ariji Y, Yanashita Y, Kutsuna S, et al. Automatic detection and classification of radiolucent lesions in the mandible on panoramic radiographs using a deep learning object detection technique. Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:424–430.
11. Lee J, Kim D, Jeong S. Diagnosis of cystic lesions using panoramic and cone beam computed tomographic images based on deep learning neural network. Oral Dis. 2020;26:152–158.
12. Sridhar M, Anjana Bagewadi, Lokesh Kumar S, Fernandes A, T Jayapriya, Arun Panwar, et al. Knowledge, attitude, and perception of dentists regarding the role of Artificial Intelligence and its applications in Oral Medicine and Radiology: a cross sectional study. Journal of oral medicine and oral surgery. 2023 Jan 1;29(2):22–2.
13. Ding H, Wu J, Zhao W, Matinlinna JP, Burrow MF, Tsoi JK. Artificial intelligence in dentistry—A review. Frontiers in Dental Medicine. 2023 Feb 20;4:1085251
14. Krois J, Ekert T, Meinhold L, Golla T, Kharbot B, Wittemeier A, et al. Deep learning for the radiographic detection of periodontal bone loss. Sci Rep. (2019) 9 (1):1–6. doi: 10.1038/s41598-019-44839-3
15. Ding H, Cui Z, Maghami E, Chen Y, Matinlinna JP, Pow EHN, et al. Morphology and mechanical performance of dental crown designed by 3D-DCGAN. Dent Mater. (2023) doi: 10.1016/j.dental.2023.02.001
16. Wei J, Peng M, Li Q, Wang Y. Evaluation of a novel computer color matching system based on the improved back-propagation neural network model. J Prosthodont. (2018) 27(8):775–83. doi: 10.1111/jopr.12561

17. Yamaguchi S, Lee C, Karaer O, Ban S, Mine A, Imazato S. Predicting the debonding of CAD/CAM composite resin crowns with AI. J Dent Res. (2019) 98 (11):1234–8. doi: 10.1177/0022034519867641
18. Gerke, S.; Babic, B.; Evgeniou, T.; Cohen, I.G. The need for a system view to regulate artificial intelligence/machine learning-based software as medical device. NPJ Digit. Med. 2020, 3, 53.
19. Nayakar R, Sardesai P, Killedar S, Patil A, Kakodker M. Knowledge, Awareness and Practices of the use of Digital Technology in Dentistry among Postgraduate Students and Dental Practitioners in India: A Cross-sectional Study. Journal of clinical and diagnostic research. 2022.
20. Singh N, Pandey A, Tikku AP, Verma P, Singh BP. Attitude, perception and barriers of dental professionals towards artificial intelligence. Journal of Oral Biology and Craniofacial Research. 2023 Sep 1;13(5):584-8.
21. Islam NM, Laughter L, Sadid-Zadeh R, et al. Adopting artificial intelligence in dental education: a model for academic leadership and innovation. J Dent Educ. 2022;86 (11):1545–1551.
22. Tandon D, Rajawat J. Present and future of artificial intelligence in dentistry. J Oral Biol Craniofacial Res. 2020;10(4):391–396.
23. Artificial intelligence in dentistry: current applications and future perspectives. Quintessence Int. 2020;51(3):248–257.
24. Sun ML, Liu Y, Liu G, et al. Application of machine learning to stomatology: a comprehensive review. IEEE Access. 2020;8:184360–184374.
25. Chen, Y.-W.; Stanley, K.; Att, W. Artificial intelligence in dentistry: Current applications and future per-spectives. Quintessence Int. 2020, 51, 248–257.
26. Kühnisch J, Meyer O, Hesenius M, Hickel R, Gruhn V. Caries detection on intraoral images using artificial intelligence. J Dent Res. 2022;101(2):158–165.
27. Ezhov M, Gusarev M, Golitsyna M, et al. Clinically applicable artificial intelligence system for dental diagnosis with CBCT. Sci Rep. 2021;11(1), 15006.
28. Ezhov M, Gusarev M, Golitsyna M, et al. Clinically applicable artificial intelligence system for dental diagnosis with CBCT. Sci Rep. 2021;11(1), 15006.
29. Pauwels R, Del Rey YC. Attitude of Brazilian dentists and dental students regarding the future role of artificial intelligence in oral radiology: a multicenter survey. Dentomaxillofac Radiol 2021;50:20200461.
30. Khanagar S, Alkathiri M, Alhamlan R et al. Knowledge, attitudes, and perceptions of dental students towards artificial intelligence in Riyadh, Saudi Arabia. Med Sci 2021;25:1857–1867.
31. Yüzbasıoglu E. Attitudes and perceptions of dental students towards artificial intelligence. J Dental Educ 2021;85:60–68.