

Dentists' Knowledge, Attitude, and Perception Regarding Robotics and Artificial Intelligence in Oral Health and Preventive Dentistry: A Cross-sectional Study

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ABSTRACT

Introduction: Robotics (R) is concerned with the linkage between perception and action, and Artificial Intelligence (AI) plays a significant role in enabling this intelligent relationship. In dentistry, AI has primarily been utilised to enhance diagnostic procedures, which are crucial for achieving favorable treatment outcomes and providing excellent patient care.

Aim: The aim of this cross-sectional study was to assess the Knowledge, Attitude, and Perception (KAP) of dentists towards R and AI in oral health and preventive dentistry.

Materials and Methods: The study was conducted at the Department of Public Health Dentistry, Yenepoya Dental College, Mangalore, Karnataka, India. The duration of the study was three months, from March 2022 to June 2022. A closed-ended, self-administered questionnaire using Google Forms was distributed among 161 dental professionals in South India. The questionnaire included items related to KAP towards the use of R and AI in preventive dentistry and oral health. Descriptive analysis was performed, and one-way Analysis of Variance (ANOVA) was used to compare mean values. Tukey's post-hoc test was employed for group comparisons.

Results: The mean age of the participants was 30.17±9.18 years. Out of the 161 participants (70 males and 91 females), 133 (82.6%) had heard about R and AI in dentistry, but only 78 (48.4%) were aware of the differences between R and AI. Among the dentists, 74 (46%) believed that AI might have a future in India, and 145 (90.6%) responded that R and AI were useful during the COVID-19 pandemic. Additionally, 97 (60.6%) participants expressed willingness to be treated by R and AI if necessary, and 107 (66.9%) would prefer to receive lectures or workshops from a robot. Tukey's post-hoc test revealed that the staff's knowledge and attitude were significantly higher than those of interns, postgraduates, and private practitioners ($p < 0.05$).

Conclusion: The findings of this study indicate that the majority of dentists have a negative perception of R and AI. Despite having a generally positive attitude, dentists have limited to no utilisation and application of R and AI. It is crucial to raise awareness of this concept in the near future, as it has the potential to enhance treatment effectiveness and efficiency.

Keywords: Coronavirus disease-2019, Dental practitioner, Diagnosis, Digital learning, Robots

INTRODUCTION

The complexity of the human brain, which consists of a network of neurons that connect and transmit information throughout the body, has long fascinated scientists and technologists. However, creating an accurate model that simulates the workings of the human brain remains a challenge for scientists. Years of ongoing research have led to the development of Artificial Intelligence (AI) [1]. In 1978, Richard Bellman defined AI as "the automation of processes related to intellect, such as learning, decision-making, and problem-solving." The impact of AI technology on modern life can be seen in the use of virtual assistants like Siri, search engines like Google Search, and video games like AlphaGo. Additionally, AI is increasingly being utilised in various fields, including medicine [2]. With the rise of AI, knowledge and skill transfer through technology are becoming increasingly important. Robotic technology reduces risks while enabling dentists to work with greater precision and less stress [3]. The term "AI" is often associated with robotics, referring to the use of technology to create software or machines that can mimic human intelligence and perform specific tasks [4].

The technological landscape has undergone significant changes in the past decade. The COVID-19 pandemic has accelerated the development of faster, less-exposed, and easier-to-manage ways of living [5]. In dentistry, AI has primarily been used to enhance

diagnostic processes, which are crucial for achieving optimal treatment outcomes and providing excellent patient care [4]. Most AI applications in dentistry are virtual, utilising AI algorithms to differentiate between lesions and healthy structures, as well as simulate and evaluate future outcomes [6]. Robots have been employed to extend the lifespan of teeth, reduce dental pain, desensitise teeth, and reposition tissue to correct misaligned teeth. In the future, robotic surgery may also be utilised for curative, restorative, and preventive dental procedures. Dental robot use has shown benefits in endodontic procedures (endomicrobots), arch wire bending, and dental implantology [7].

The fundamental components of AI widely applied in dentistry include Artificial Neural Networks (ANN), Machine Learning (ML), fuzzy logic, telemedicine, Computer-aided Design (CAD)/Computer-aided Manufacturing (CAM), nano dentistry, digital smile designing, and dynamic navigational implant placement. Advancements in AI are gradually expanding its application in dentistry, encompassing fields such as radiography, orthodontics, restorative and prosthetic dentistry, endodontics, implantology, and the recent addition of voice-command dental chairs [8]. Digital approaches in preventative dentistry and oral health care are being increasingly utilised worldwide, experiencing exponential growth. To effectively implement robotics (R) and AI in the dental industry, dental students, graduates, and

practitioners need to acquire skills in utilising cutting-edge digital dentistry technologies. However, R and AI are often not covered in the standard dental curriculum. Despite previous attempts to assess dental students' attitudes towards the use of R/AI technology in dental education, it remains unknown how prevalent such training is among dental students, graduates, and practitioners, as well as their level of R/AI proficiency. In order to engage dentists in this discussion, it would also be beneficial to understand their perspectives on R/AI. Hence, the present study was conducted to determine the Knowledge, Attitude, and Perception (KAP) of dentists regarding the role of R and AI in oral health and preventive dentistry in South India.

MATERIALS AND METHODS

A cross-sectional study was conducted at the Department of Public Health Dentistry, Yenepoya Dental College, Mangalore, Karnataka, India, over a duration of three months from March 2022 to June 2022. An online survey based on Knowledge, Attitude, and Perception (KAP) regarding R and AI was conducted. The study was conducted on an online platform and encompassed participants from all over South India, using WhatsApp (version 2.2) for data collection. Ethical approval was obtained from the Institutional Ethics Committee (IEC2/1061).

Inclusion criteria: The study included dental interns and dental graduates (postgraduates, teaching faculty, and private practitioners) engaged in dental practice in any geographical location or area in South India were included in the study.

Exclusion criteria: Participants who were not willing to give informed consent for participation were excluded from the study.

Sample size calculation: With a 95% confidence level, a knowledge percentage of 58.3% [7], and a margin of error of 8%, the calculated sample size was 146. Considering a 10% non-response error rate, a total of 161 participants were enrolled in the study using convenience sampling.

Study Procedure

Participants were provided with information about the research and the study's contents through a participant information sheet. Informed consent was obtained from the participants, and participation in the study was voluntary. Full confidentiality of the collected data was ensured.

Online questionnaire: The research team developed a specific 24-item online questionnaire for the present study, taking into account previously conducted similar studies [7]. The questionnaire included participant demographics (gender, qualification, occupation, and age in years) and KAP regarding R and AI in oral health and preventive dentistry.

The questionnaire was created using Google Forms and had three response options: yes, no, and not sure/maybe/I don't know/neutral. Scores were assigned as follows: 2 for yes, 1 for no, and 0 for all other responses. Higher scores indicated a positive understanding, lower scores indicated a negative understanding, and no score indicated no view on R and AI in dentistry. The scoring criteria were as follows:

- Knowledge - Good knowledge: 9-16; Poor knowledge: <8
- Attitude - Positive attitude: 11-21; Negative attitude: <10
- Perception - Positive perception: 3-4; Negative perception: <2

The initial study questionnaire was created in Microsoft Office Word and later converted into a Google Form for online data collection. The study questionnaire could be completed in 5-10 minutes. Prior to the study, the questionnaire was pilot tested on five subjects, and suggestions from study experts were incorporated.

Despite sending multiple reminders, not all contacts responded to confirm if the questionnaire had been shared.

STATISTICAL ANALYSIS

The data from the study conducted on Google Forms was downloaded and then data cleaning and coding were performed on a Microsoft Excel sheet. Data analysis was conducted using Statistical Package for the Social Sciences (SPSS) version 27.0 (IBM, Armonk, NY, United States of America). Descriptive analysis was performed, with qualitative variables expressed as percentages and proportions, and quantitative data expressed as mean and standard deviation (SD). The normality test indicated a normal distribution of the data. One-way ANOVA was used to compare the mean values of Knowledge, Attitude, and Perception (KAP), and Tukey's post-hoc test was used for pairwise comparisons between groups. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 161 dentists participated in the present study. The mean age of the participants was 30.17±9.18 years. Among the study participants, 70 (43.5%) were male and 91 (56.5%) were female. In the present study, out of the 161 participants, 47 (29.2%) were interns, 47 (29.2%) were postgraduates, 47 (29.2%) were private practitioners, and 20 (12.4%) were teaching faculty from all over South India via an online platform [Table/Fig-1].

In the present study, the mean score for Knowledge, Attitude, and Perception (KAP) was highest among the teaching staff [Table/Fig-2].

Demographic variables		n (%)
Gender	Male	70 (43.5)
	Female	91 (56.5)
Qualification	BDS	86 (53.4)
	MDS	75 (46.6)
	PhD	0
	Others (diploma)	0
Occupation	Intern	47 (29.2)
	Postgraduate	47 (29.2)
	Private practitioner	47 (29.2)
	Teaching faculty	20 (12.4)

[Table/Fig-1]: Demographic data of participants.

BDS: Bachelor of dental surgery; MDS: Master of dental surgery; PhD: Doctor of philosophy (N=161)

Variables	Interns	Postgraduates	Private practitioners	Staffs
Knowledge	10.51±2.99	11.17±3.61	11.68±3.26	14.1±1.86
Attitude	14.72±2.96	15.06±3.22	15.0±3.07	17.25±2.77
Perception	2.57±0.77	2.76±0.75	2.70±0.72	2.85±0.48

[Table/Fig-2]: Mean score of knowledge, attitude and perception among each group (Mean±SD).

Description of knowledge-related questions: The results of the present study indicated that 63 (39.2%) participants agreed that they would use AI for dental diagnosis, 48 (29.8%) stated that they would use AI for treatment planning, 29 (18%) for direct treatment, and 21 (13%) would utilise AI for interpreting complicated radiographs. A total of 74 (46%) dentists think AI might have a future in India, while 79 (49%) participants strongly believed that R and AI have a future in India [Table/Fig-3]. A Tukey's post-hoc test revealed that the staff's knowledge was significantly higher than interns ($p=0.001$), postgraduates ($p=0.004$), and private practitioners ($p=0.030$). There was no significant difference found between interns with postgraduates and private practitioners, as well as between postgraduates and private practitioners [Table/Fig-4].

Description of perception-related questions: In terms of perception regarding which department requires AI to increase the quality of treatment, 53 (32.9%) responded oral maxillofacial surgery, while 50 (31.1%), 43 (26.7%), and 35 (21.7%) responded prosthodontics crown and bridge, implantology, conservative dentistry

Questions related to knowledge	Yes n (%)	No n (%)	Not sure/May be/ I don't know n (%)
Have you heard about AI and R in dentistry (Q1)	133 (82.6)	28 (17.4)	-
Do you know the difference between AI and R? (Q2)	78 (48.4)	61 (37.9)	22 (13.7)
Do you have any idea of how AI and R can be incorporated in dental practice? (Q3)	54 (33.5)	93 (57.8)	14 (8.7)
Do you think AI and R has a future in dentistry in India? (Q4)	79 (49)	8 (5)	74 (46)
Do you think AI and R will help budding dentists in diagnosis and decision making? (Q5)	86 (53.4)	8 (5)	67 (41.6)
Do you think AI and R were useful during Covid-19 pandemic? (Q6)*	145 (90.6)	15 (9.4)	-
Do you think R technology can be used to assist with patient diagnosis and the development of an integrated treatment plan? (Q7)*	114 (71.3)	11 (6.8)	35 (21.9)
Do you think AI can be used in examinations and their interpretation, e.g., radiographs, CBCT, MRI, differentiation between vital and pathological signs? (Q9)	117 (72.7)	14 (8.7)	30 (18.6)

[Table/Fig-3]: Knowledge regarding Robotics (R) and Artificial Intelligence (AI).
*Total doesn't add upto 161 because of missing responses; CBCT: Cone-beam computed tomography systems; MRI: Magnetic resonance imaging
n: Number of participants; %: Percentage

Variables	Mean difference	p-value	95% Confidence interval	
			Lower bound	Upper bound
Interns with postgraduates	-0.660	0.743	-2.35	1.03
Interns with private practioner	-1.234	0.236	-2.93	0.46
Interns with teaching faculty	-3.589	0.001*	-5.78	-1.40
Postgraduates with private practioner	-0.574	0.815	-2.27	1.12
Postgraduates with teaching faculty	-2.930	0.004*	-5.12	-0.74
Private practioner with teaching faculty	-2.355	0.030*	-4.55	-0.16

[Table/Fig-4]: Overall knowledge in terms of occupation.
*The mean difference is significant at the 0.05 level

and endodontics, and orthodontics and dentofacial orthopedics, respectively. A total of 62 (39%) participants perceived CAD/CAM to be a contribution of R and AI in dentistry, while 49 (31%) participants considered predicting the correct placement of implants, and 35 (22%) responded teeth arrangement, and 52 (33%) opted for reducing treatment errors in endodontics. A total of 86 (54.7%) participants considered the general contribution of R in dentistry to be in the dental curriculum, while 62 (39.4%) participants considered the contribution to be in enhanced career growth, and 21 (13.3%) of them believed that it contributed to increased awareness in the community and individuals. Participants were able to choose more than one of the provided choices [Table/Fig-5]. A Tukey's post-hoc test revealed that there was no statistically significant difference between any of the groups regarding perception [Table/Fig-6].

Questions related to perception	Yes n (%)	No n (%)	I don't know n (%)
Can AI replace dentists permanently? (Q13)*	4 (2.5)	143 (90)	12 (7.5)
AI facilitates the preservation of patient information, data and accessibility, quickly and accurately. (Q14)	139 (86.3)	6 (3.7)	16 (10)

[Table/Fig-5]: Perception regarding R and AI.
*Total doesn't add upto 161 because of missing responses

Description of attitude-related questions: Description of attitude-related questions: Almost half of the participants, 81 (50.9%), favored the use of AI in dental colleges, while 47 (29.6%) favored it at specialised clinics, and 31 (19.5%) favored it at public health

Variables	Mean difference	p-value	95% Confidence interval	
			Lower bound	Upper bound
Interns with postgraduates	-0.191	0.576	-0.58	0.20
Interns with private practioner	-0.128	0.828	-0.52	0.26
Interns with teaching faculty	-0.276	0.485	-0.78	0.23
Postgraduates with private practioner	0.064	0.974	-0.32	0.45
Postgraduates with teaching faculty	-0.084	0.972	-0.59	0.42
Private practioner with teaching faculty	-0.148	0.870	-0.65	0.35

[Table/Fig-6]: Overall perception in terms of occupation.
*The mean difference is significant at the 0.05 level

centres. The majority of the participants, 73 (45%), felt that receiving information from a robot would not increase their self-confidence compared to a traditional classroom. Among the study participants, 98 (61%) felt that R and AI would enhance their clinical practice [Table/Fig-7].

Questions related to attitude	Yes n (%)	No n (%)	Neutral n (%)
Would you recommend diagnosis done with AI and R? (Q15)	134 (83.2)	27 (16.8)	-
Would you prefer treatment with AI and R done on yourself, if needed? (Q16)*	97 (60.6)	63 (39.4)	-
Would you prefer to work in the robot simulation lab for training in endodontics, crowns, bridges and fillings etc.,? (Q17)	151 (93.8)	10 (6.2)	-
Would you prefer to receive lectures or workshops from a robot? (Q18)*	107 (66.9)	17 (10.6)	36 (22.5)
In your opinion, does receiving information from a teaching robot increase self-confidence more than in a traditional classroom? (Q19)	36 (22.4)	73 (45.3)	52 (32.3)
If you had the opportunity to work in a team that included a robot as a participant, would you agree to join? (Q20)	113 (70.2)	10 (6.2)	38 (23.6)
Would you like to learn about AI and R in the future? (Q21)*	127 (79.8)	2 (1.3)	30 (18.9)
If the time come for students, doctors and individuals working in the university to accept AI and R techniques? (Q22)	110 (68.3)	9 (5.6)	42 (26.1)
Do you feel that application of AI and R could enhance your clinical practice? (Q23)*	98 (61.3)	8 (5)	54 (33.7)

[Table/Fig-7]: Attitude regarding Robotics (R) and Artificial Intelligence (AI).
*Total doesn't add upto 161 because of missing responses

A Tukey's post-hoc test revealed that the staff's attitude was significantly higher than interns ($p=0.012$), postgraduates ($p=0.040$), and private practitioners ($p=0.032$). There was no statistically significant difference between interns with postgraduates and private practitioners, as well as between postgraduates and private practitioners [Table/Fig-8].

Variables	Mean difference	p-value	95% Confidence interval	
			Lower bound	Upper bound
Interns with postgraduates	-0.340	0.949	-1.97	1.29
Interns with private practioner	-0.277	0.971	-1.91	1.36
Interns with teaching faculty	-2.527	0.012*	-4.64	-0.41
Postgraduates with private practioner	-0.064	1.000	-1.57	1.70
Postgraduates with teaching faculty	-2.186	0.040*	-4.30	-0.07
Private practioner with teaching faculty	-2.250	0.032*	-4.36	-0.14

[Table/Fig-8]: Overall attitude in terms of occupation.
*The mean difference is significant at the 0.05 level

DISCUSSION

It is well known that R and AI have a significant impact on the medical sector. Increasing studies have shown that R and AI are also affecting dentistry. The present study indicated that 83% of the participants had heard about R and AI in dentistry. The majority of dentists were aware of R and AI and recognised its importance within the dental profession. However, only half of the respondents understood the distinction between robotics and AI. According to Abouzeid HL et al., 70% of dentistry students who were asked if they knew the difference between AI and R responded “No” [7]. Robotics, which interacts with mechanical components such as computers, effectors, and sensors, utilises AI in its reasoning and perception. Only 39% of the participants in the study had a fundamental understanding of how AI could be used in dental practices, which aligns with the findings of Keser G and Pekiner FM [9].

According to the present survey, the majority of respondents (95%) thought that R and AI would flourish in India. Similarly, two-thirds of the participants in the study conducted by Sur J et al. [10] indicated that AI can have a future in India. Since AI is still a relatively new technology, India currently lacks a regulatory system focused on it. The study also found that most dentists believed R and AI were useful during the COVID-19 pandemic. The pandemic has put strain on the healthcare infrastructure, exacerbating already challenging situations. Discussing how AI can help modernise the industry, the study highlights its potential in prompt pandemic outbreak prediction, remote diagnosis and treatment, and effective health resource allocation. Overall, the study found that participants generally had good knowledge of R and AI in dentistry. The findings demonstrate that learning is an ongoing process, as both students and senior dentists were eager to expand their knowledge. However, as mentioned earlier, India lacks a regulatory system to fully utilise the knowledge of R and AI possessed by dental professionals in the country.

Microendodontic robots, as reported by Abouzeid HL et al., may have the potential to treat patients with root canals in a safe, accurate, and reliable manner, reducing reliance on individual dentists' abilities and minimising human error [7]. At the cellular and molecular levels, nano diagnostic tools can be utilised for early disease detection. Dental nanorobots may employ specialised motility mechanisms to navigate human tissues with precision, gather energy, and detect and manipulate their environment in real time. However, only 33% of participants in the present study believed that the best contribution of R and AI in dentistry was reducing treatment errors in endodontics. Similar to research in radiology and other medical fields, Abouzeid HL et al. reported that 40% of participants believed that R and AI will not completely replace dentists [7]. In the present study, however, 90% of participants held the same belief. Approximately 35% of participants thought this transformation would occur in the future, while 25% were unsure. These findings align with the results reported by Keser G and Pekiner FM [9]. This serves as a warning to dentists that the significance of R and AI in dentistry should not be underestimated, and there is an urgent need to improve training and expertise in this area. Participants in the present study generally had negative perceptions about R and AI. This could be interpreted as a caution against the use of R and AI in clinical settings, but it also demonstrates that better patient care is possible with the appropriate application of this technology. The issue lies in the basic curriculum of dentistry, as current BDS courses do not expose graduates to the advancements in R and AI technology in dentistry. Even if some topics are discussed, their specific importance is not emphasised, resulting in the field remaining unexplored.

The majority of participants, 61%, felt that R and AI would enhance their clinical practice. Similarly, according to Abouzeid HL et al.,

over 60% of participants answered “yes” regarding the application of R and AI in enhancing clinical practice [7]. With robots providing high-quality work in less chair time, it is time for dentists and dental students to start utilising them in clinical practice. The acceptance and reception of current technology by patients will play a significant role in the future transformation of dentistry through robots.

Among the study participants, 45% felt that receiving information from a robot would not increase their self-confidence compared to a traditional classroom setting, while 23% preferred receiving information from a robot. It is important to give special consideration to R and AI in education, as a well-defined curriculum should be created to improve the role of robotics in teaching. Specific curricula, learning materials, and teacher training programs should be developed for different types of robotic technology and levels of dentistry instruction [7].

Regarding the commercialisation of AI, 51% of participants suggested dental colleges as the first choice, followed by specialised clinics (30%) and public health centers (19%). The role of AI in healthcare has been a topic of great interest in recent years. These results once again demonstrate the interest of dentists in new technologies such as AI and their willingness to learn. Among the study participants, staff members showed higher knowledge and attitude compared to interns, postgraduates, and private practitioners regarding R and AI in oral health and preventive dentistry.

Limitation(s)

The findings should not be generalised as inherent limitations of cross-sectional studies, closed-ended questionnaires (which may limit participants' suggestions or ideas and oversimplify complex questions), and non-probability sampling techniques (which depend heavily on the expertise of the researchers) should be considered. Future studies are recommended to cover the entire nation, providing a more comprehensive understanding of R and AI among working dentists.

CONCLUSION(S)

In conclusion, based on the results of the present study, it is important for dental education to adapt to the increasing integration of AI-enabled technology in healthcare in order to produce competent doctors who can provide excellent patient care. This can be achieved by incorporating R and AI into the undergraduate curriculum and offering continuing dental education programs. Future studies are recommended to provide a more comprehensive understanding of R and AI among working dentists in different specialties.

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