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Nationwide exploration: assessing oral microbiome knowledge among dental professionals in Saudi Arabia and its implications for oral health care

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Abstract

Background The relationship between the microbiome and oral health is intricate, yet there is a lack of comprehensive knowledge regarding the microbiome's impact on oral health. Integrating knowledge regarding the oral microbiome and its significance in oral and systemic diseases holds profound implications for dental professionals in patient care and professional development. This study assessed dental professionals' oral microbiome comprehension and knowledge levels in Saudi Arabia and its implications for oral healthcare.

Methods Data were gathered using a cross-sectional design by administering a comprehensive online questionnaire to 253 dental professionals from diverse demographic backgrounds. The questionnaire, administered in English, was divided into four sections: (1) Microbiome awareness and understanding, (2) Diet, nutrition, and microbiome relationship, (3) Microbiome and oral and systemic diseases, and (4) Counselling, education, and implications. Statistical analyses were used to identify and understand underlying patterns, including descriptive statistics, chi-squared tests, ANOVA, and post hoc tests. The Spearman rank correlation coefficient was applied to assess self-rated knowledge.

Results Of the 253 participants, 94.6% were familiar with the term "microbiome." Merely 13% of participants considered the oral microbiome to be the second most diverse, following the gut microbiome. About 39.9% of participants knew the connection between oral mucosal diseases and the oral microbiome. Furthermore, only 6.7% thought there was a connection between systemic diseases and the oral microbiome. Participant comprehension of oral microbiome questions averaged 9.19 out of 13, with 83.7% scoring "good". There were significant differences in knowledge scores among dental specializations ($F = 7.082$, $P < 0.001$) and years of professional experience ($F = 4.755$, $P = 0.003$). Significantly, 53.8% of participants had uncertain self-perceptions of their knowledge of the oral microbiome, while only 0.8% rated their understanding as 'very good'.

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Conclusion Our findings reveal that dental professionals have varying levels of awareness and comprehension of the oral microbiome. Despite widespread awareness, understanding its diversity and implications for oral and systemic health remains limited. It is essential to address these gaps in knowledge through future research and educational interventions, considering the vital part that dental professionals play in promoting oral health through personalised dietary recommendations, lifestyle changes, and hygiene practices. These initiatives may promote a robust oral microbial community, enhance patient outcomes, and advance oral healthcare locally and globally.

Keywords Oral microbiome, Dental practitioners, Saudi Arabia, Knowledge assessment, Oral health care

Background

Over millennia, our indigenous microorganisms have evolved alongside us, forging a harmonious symbiotic relationship. We are not solitary entities but rather composite beings, forming a 'superorganism' or holobiont, where the microbiome intricately influences our physiology and health [1]. The oral cavity contains the second most varied microbial population in the body, with more than 700 bacterial species inhabiting the tooth surfaces of the mouth and soft tissues interacting intricately with various external factors, including nutrition [2]. Recent technological advances have revealed the complex nature of the oral microbiome, providing new insights into its functions in healthy and diseased states [3–5].

Dysbiosis, which refers to an imbalance in the microbial community, disrupts the delicate balance of the oral ecosystem and fosters the emergence of disease-promoting bacteria. Disruptions to the oral microbiome, driven by contemporary lifestyles, can detrimentally impact our oral and overall health [6, 7]. The complex relationship between the oral microbiome and these conditions underscores the critical role of microbial dysbiosis in the development of various oral diseases. It is well established that the oral microbiome influences oral diseases, including dental caries [8, 9], periodontitis [9–11], recurrent aphthous ulcers (RAU) [12, 13], candidiasis [14, 15] and oral squamous cell carcinoma (OSCC) [16–18]. Moreover, mounting evidence highlights the interdependence of oral and gut microbial ecosystems, linking oral microbiome dysbiosis to systemic diseases such as obesity [11, 19, 20], diabetes mellitus (DM) [21–23], cardiovascular disease (CVD) [24, 25], rheumatoid arthritis (RA) [26, 27], Alzheimer's disease [28, 29], colorectal cancer [30, 31], preterm birth [32], and inflammatory bowel disease (IBD) [33, 34]. Furthermore, alterations in the oral microbiome during systemic diseases occur gradually and consistently. Thus, oral microbes can serve as real-time indicators of human health and disease status, making them valuable for the early detection of disease risk and the prediction of treatment effectiveness [35–37].

With rapid advancements in microbiome research, dental professionals are at the forefront of applying this knowledge to clinical practice [38]. Despite this, a comprehensive review of scientific databases revealed a notable gap in understanding the role of the oral microbiome in health and illness among dental professionals, particularly in Saudi Arabia. Thus, our study aimed to assess Saudi dental professionals understanding and awareness of the oral microbiome, elucidating its significance in oral health care. By examining demographic variables such as age, gender, years of professional experience, and dental specializations, we aim to identify knowledge disparities. Understanding the intricate correlation between the oral microbiome and health/disease status enables dental professionals to adopt a comprehensive approach to patient care, dietary counselling, optimizing treatment outcomes, minimizing the risk of disease recurrence, and hygiene practices that nurture a harmonious oral microbial community. Ultimately, enhancing the understanding of the role of the oral microbiome may revolutionize dental practice, improving patient outcomes and advancing oral healthcare locally and globally.

Methodology

Study design and setting

This cross-sectional study aimed to determine the level of knowledge and awareness among Saudi dental professionals about the role of the oral microbiome in health and disease. The Jazan University Standing Committee on the Ethics of Scientific Research (REC-45/05/895, HAPO-10-Z-001) approved the study, ensuring that ethical guidelines were followed. Dental professionals from various regions of Saudi Arabia, affiliated with government institutions, private clinics, and teaching institutes, were invited to participate in the study, ensuring a diverse representation of the dental community.

Development and content of the questionnaire

The questionnaire was carefully crafted to assess dental professional's comprehension of the oral microbiome, its functions, and its impact on oral and systemic diseases. Multiple essential measures were implemented throughout the development process to ensure the questionnaire's pertinence, accuracy, and consistency. An extensive review of the literature on the oral and gut microbiome, oral health, and diseases was conducted to identify the relevant topics and subjects that should be included in the questionnaire. The literature review established a robust theoretical foundation for the questionnaire topic. An expert panel specializing in the oral microbiome and

dentistry assessed the initial version of the questionnaire to establish its face and content validity. The input from the experts played a vital role in enhancing the questionnaire to effectively cover the extensive range of knowledge required to achieve the study objectives. A list of developed questionnaires is presented in supplementary Table 1. The questionnaire, administered in English, was divided into four sections: (1) Microbiome awareness and understanding, (2) Diet, nutrition, and microbiome relationship, (3) Microbiome and oral and systemic diseases, and (4) Counselling, education, and implications. A preliminary trial was conducted at Jazan University's College of Dentistry to test the questionnaire. The trial involved a sample of 20 dental professionals. The pilot study sought to evaluate the internal reliability of the questionnaire using statistical analysis techniques, such as calculating the Cronbach's alpha coefficient (0.81). The feedback provided by the participants in the pilot study was used to evaluate the reliability and validity of the questionnaire. This feedback led to additional improvements before the final version was completed.

Data collection process

The completed questionnaire, comprising 14 items, included responses such as "Yes," "No," and "I do not know". It was distributed electronically to dental professionals throughout Saudi Arabia. Diverse communication channels, such as social media platforms and professional networks, were employed to target potential participants. The questionnaire was designed to collect data regarding participants' familiarity with the oral microbiome, guaranteeing a thorough evaluation of their awareness and comprehension. Enrolment in the study was optional and confidential, and informed consent was obtained from all participants before the data were collected. The study process strictly adhered to ethical considerations, including confidentiality and data protection, following the principles of the Helsinki Declaration (IRB: OM; 0219).

Inclusion and exclusion criteria

The study included dental professionals actively practicing in Saudi Arabia, encompassing those affiliated with government institutions, private clinics, and teaching institutes. Exclusion criteria involved non-licensed individuals, those not practicing, and professionals outside Saudi Arabia. We initially aimed to recruit 384 participants for the sample size calculation based on the formula for estimating proportions in a finite population, considering a 95% confidence level and a 5% margin of error. However, due to practical constraints, such as excluding non-licensed and non-practicing individuals, we could include 253 participants in the study. Despite this reduction, the sample size is sufficient to achieve the study's objectives.

Statistical analysis

The response data were acquired as an MS Excel spreadsheet and subsequently imported into a statistical program. The data were analyzed using the Statistical Package for Social Sciences (SPSS) software, version 23.0, developed by IBM Corp. in Armonk, NY, USA. Chi-squared tests and one-way ANOVA were used at each study stage to evaluate the relationships between the acquired knowledge and various variables. Post hoc Tukey analysis was employed to conduct multiple comparisons. The Spearman rank correlation coefficient was applied for the assessment of self-rated knowledge.

Results

The participants' sociodemographic variables were analyzed and are presented in Fig. 1. The study included a total of 253 participants. Regarding age distribution, the study revealed that most participants, specifically 113 participants or 44.7% of the total sample, were between 41 and 50 years of age. Fifty-six participants, representing 22.1% of the sample, were between 30 and 40 years old. In contrast, 55 participants (21.7%) were under age 30, and only 2 participants (0.8%) were over age 60. Regarding gender, females accounted for 133 participants, or 52.6% of the total. The remaining 120 participants (47.4%) were male. The analysis of dental health care specializations showed that the largest group consisted of general dentists, with 48 participants (19.0%). They were followed by 36 (14.2%) oral medicine specialists and 30 (11.9%) of prosthodontists. The smallest subset consisted of oral pathologists, accounting for 11 (4.3%) of the sample. In terms of workplace, the participants were divided among different sectors. Specifically, 78 participants (30.9%) worked in government institutions, 76 participants (30.0%) worked in private clinics, and 99 participants (39.1%) worked in teaching institutes. The participants demonstrated a range of experience levels, with 83 participants (32.8%) practising for 11 to 20 years, 68 participants (26.9%) practising for less than 5 years, 53 participants (20.9%) practising for 5 to 10 years, and 49 participants (19.4%) practising for more than 20 years.

The following graph visually depicts the socio-demographic attributes of the participants. The data emphasises the allocation among various age categories, revealing that the most common age range is between 41 and 50. Furthermore, it demonstrates the gender breakdown, with females having a slightly higher representation. The figure also illustrates the distribution of participants among different dental healthcare specializations, workplace settings, and years of practice, giving a thorough overview of the sample demographics.

The participants' responses to each question were summarized and classified into "Yes," "No," and "I do not know" categories. Regarding awareness and

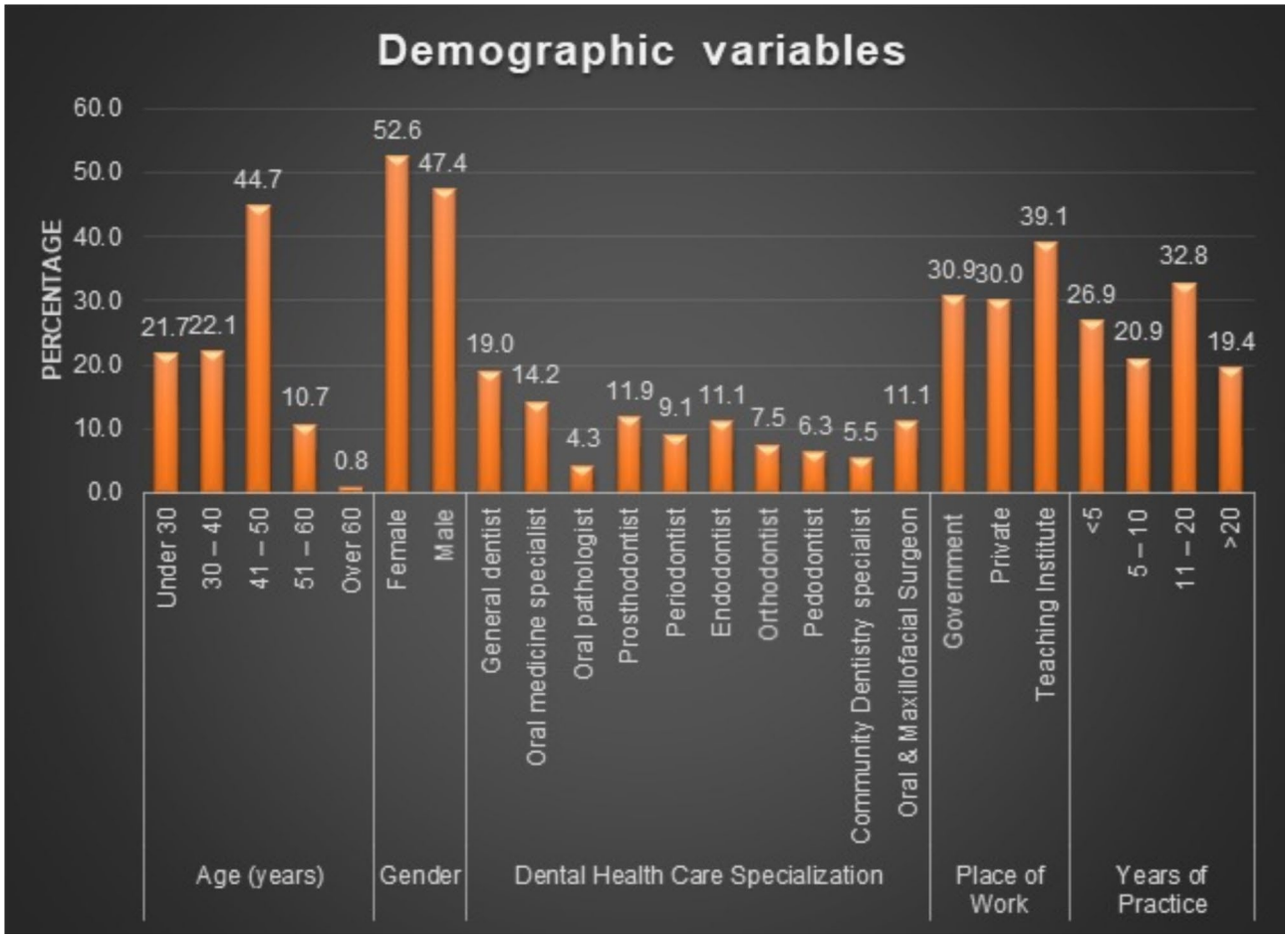

Fig. 1 Displays the distribution of socio-demographic variables among the participants

comprehension of the microbiome (Q1-Q3), a significant proportion of participants (94.9%) expressed familiarity with the term "microbiome," whereas a smaller percentage (5.1%) were knowledgeable about its diversity in the oral cavity. Regarding dysbiosis and symbiosis, the consensus among the majority is that imbalances can impact health conditions and diseases, with 85.8% agreement. Regarding the connections between diet, nutrition, and the microbiome (Q4-Q6), a considerable percentage of respondents acknowledged that diet impacts the microbiome (79%). Furthermore, most respondents (89.3%) recognized that fiber, prebiotics, and probiotics affect the diversity and function of microbes. Additionally, a significant proportion of respondents (64.4%) agreed that consuming unprocessed plant foods contributes to gut microbiome health. Regarding the role of the microbiome in oral and systemic diseases (Q7-Q10), most participants acknowledged the connection between inadequate oral hygiene and health problems affecting the entire body (96.0%). Additionally, they believed that the oral microbiome was involved in dental caries and periodontal disease (91.7%). Nevertheless, fewer participants agreed regarding the presence of crosstalk between modified oral microbiota and epithelial barriers in oral mucosal diseases (39.9%) and the potential influence of the oral microbiome in systemic diseases (6.7%). Regarding counselling, education, and implications (Q11-Q13), the majority of respondents agreed on the following points: nutritional counselling in dental practice can have a positive impact on the microbiome and oral health outcomes (80.2%), advancements in the oral-gut axis could result in new diagnostics and treatments (91.3%), and dental professionals should receive specialized training in nutritional counselling (94.8%). The results of this study provide valuable information about how participants in the dental community perceive and understand concepts related to the microbiome. The findings reveal both areas of agreement and potential gaps in knowledge, as shown in Table 1 and as suplimentary Fig. 1 displayed in the supplementary file.

An analysis of the knowledge scores, based on the responses to 13 questions, revealed 253 participants in the sample. The average knowledge score was 9.19, with a standard deviation of ±1.834. The scores varied

Table 1 Summary of response to each question among participants ('Yes', 'No', 'I do not know')

Microbiome Awareness and Understanding	Yes		No		I do not know	
	N	%	*N*	%	*N*	%
Q1. Are you familiar with the term "microbiome," which refers to the collection of bacteria, fungi, viruses, and protozoa that reside in various parts of the gut and oral cavity?	240	94.9	2	0.8	11	4.3
Q2. The microbiome of the oral cavity is among the second most diverse, following that of the gut.	**13**	**5.1**	**234**	**92.5**	**6**	**2.4**
Q3. Dysbiosis refers to an imbalance of the microbial community, while symbiosis indicates a balanced microbial community. Do you agree that these imbalances can impact various health conditions and diseases?	**217**	**85.8**	**19**	**7.5**	**17**	**6.7**
Diet, Nutrition and Microbiome Relationship:						
Q4. Do you believe our diet can influence the microbiome living in our bodies, such as those in the gut and oral cavity?	**200**	**79**	**9**	**3.6**	**44**	**17.4**
Q5 Fiber, prebiotics, and probiotics are believed to affect microbe diversity and function in these ecosystems. Do you agree with this statement?	**226**	**89.3**	**5**	**2.0**	**22**	**8.7**
Q6. Eating more unprocessed plant foods — fruits, vegetables, nuts, seeds, and whole grains — allows the gut microbiome to thrive. Do you agree with this statement?	**163**	**64.4**	**19**	**7.5**	**71**	**28.1**
Microbiome and Oral and Systemic diseases:						
Q7. Poor oral hygiene practices resulting in altered composition of the microbiome can lead to changes in the oral microbiome that may contribute to systemic health problems	243	96.0	5	2.0	5	2.0
Q8. The oral microbial dysbiosis plays a primary role in initiating dental caries and periodontitis	232	91.7	5	2.0	16	6.3
Q9 Crosstalk exists between the altered oral microbiota and epithelial barrier in oral mucosal diseases such as Oral lichen planus (OLP), Recurrent aphthous ulcers, and Oral squamous cell carcinoma	101	39.9	86	34.0	66	26.1
Q10 Do you believe that the composition of the oral microbiome may play a role in systemic diseases such as Obesity, Alzheimer's, Inflammatory bowel disease, Diabetes, cardiovascular diseases, and Rheumatoid arthritis?	17	6.7	144	56.9	92	36.4
Counselling, Education and Implications:						
11. Can incorporating nutritional counselling into routine dental practice positively impact patients' microbiome and oral health outcomes	203	80.2	10	4.0	40	15.8
12. Do you agree that advancements in understanding the oral-gut axis could lead to novel diagnostics, therapeutics, and health management methods?	231	91.3	6	2.4	16	6.3
13. Should dental professionals receive specific training on incorporating nutritional counselling into routine dental practice to positively impact patients' oral health outcomes?	240	94.8	2	0.8	11	4.4

Table 1 The table presents a thorough summary of participant responses to questions designed to evaluate the level of awareness and comprehension of the oral microbiome among dental professionals. The questions explore various facets of microbiome understanding, and the answers are classified as either "Yes," "No," or "I don't know." 94.9% of participants responded positively, indicating a significant familiarity with the term "microbiome." Nevertheless, there is a notable disparity in comprehension regarding the diversity of the oral microbiome, as only 5.1% of participants concur that it ranks among the most diverse microbial communities. This discovery implies a possible need for clarification or education among dental professionals. In addition, the response rates for questions regarding the correlation between the oral microbiome and oral mucosal diseases (Q9) and systemic diseases (Q10) were significantly lower. Just 39.9% of participants recognised the connection between changes in oral microbiota and the epithelial barrier in oral mucosal diseases, and an even smaller percentage (6.7%) accepted the significance of the oral microbiome in systemic diseases. These findings highlight the possibility of participants lacking knowledge or awareness about the wider consequences of the oral microbiome beyond oral health. In the counselling, education, and implications section, 80.2% of the participants concurred that integrating nutritional counselling into regular dental practice could benefit patients' microbiome and oral health results. Similarly, a substantial percentage (91.3%) recognised the potential advantages of progress in comprehending the oral-gut axis. Nevertheless, a minority of participants (4.0% and 2.4%, respectively) exhibited doubt, highlighting the need for additional education or awareness

between 2 and 12, with a median score of 10 and an interquartile range (IQR) of 8 to 11. Specifically, 2.0% of the participants were classified as having "very good" knowledge, 83.7% as having "good" knowledge, 10.3% as having "poor" knowledge, and 4.0% as having "very poor" knowledge. This classification system was chosen to provide a simple and clear interpretation of the participants' knowledge levels. It aids in determining areas of strong knowledge and those that may require additional education or training. The thresholds were established to distinguish between different levels of understanding, ensuring that the findings are meaningful and actionable for increasing dental professionals' awareness and comprehension of the oral microbiome. A summary of the distribution of knowledge scores among the participants, highlighting the different levels of understanding among the surveyed population, is presented in Table 2.

The knowledge scores of 253 participants based on their responses to 13 questions show an average score of 9.19, with a standard deviation of 1.834. The scores varied between 2 and 12, with a median value of 10. The majority of participants (83.7%) obtained a score categorised as "good," while a small percentage (2.0%) achieved a score classified as "very good." Nevertheless, 10.3% of Saudi Arabian dental professionals obtained "poor" scores, while 4.0% obtained "very poor" scores, highlighting the need to improve their understanding of the oral microbiome.

The study examines the relationship between participants' age and knowledge scores, categorizing them into various age groups, from individuals under 30 to those

Table 2 Descriptive analysis of knowledge score based on 13 questions among participants

N		253
Mean		9.19
± Standard deviation		1.834
Minimum		2
Maximum		12
Median		10
IQR (Inter Quartile Range)		8–11
Categories of knowledge score based on 13 questions		
Category	N	%
Very good	5	2.0
Good	212	83.7
Poor	26	10.3
Very poor	10	4.0

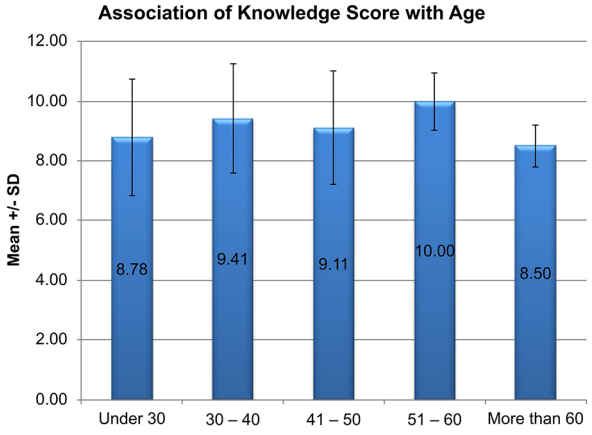

Fig. 2 Illustrates the relationship between knowledge scores and age groups among participants

over 60. The average knowledge score for participants under the age of 30 was 8.78, with a standard deviation of 1.960. The scores ranged from 4 to 11. Within the age range of 30–40 years, the average knowledge score was 9.41 (±standard deviation=1.827), with scores varying from 4 to 12. The average knowledge score of participants between 41 and 50 years of age was 9.11, with a standard deviation of 1.892. The scores ranged from 2 to 12. The individuals between the ages of 51 and 60 had an average knowledge score of 10.00 (±standard deviation=0.961), with scores ranging from 8 to 12. Participants aged 60 and above had an average knowledge score of 8.50 (±standard deviation=0.707), with scores ranging from 8 to 9. The analysis revealed a significant correlation between age and knowledge score (ANOVA: F=2.381; *P*=0.052), although the difference did not reach statistical significance, as displayed in Fig. 2.

Among individuals under 30 (*N*=55), the average knowledge score was 8.78 (SD=1.960), ranging from 4 to 11. In 56 people aged 30–40, the average score was 9.41, with a standard deviation of 1.827. Scores were

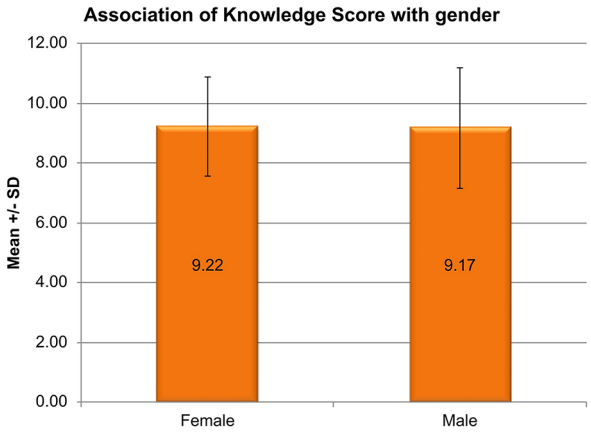

Fig. 3 Illustrates the association of knowledge scores with gender among the participants

4–12. In the 41–50 age group (*N*=113), the average score was 9.11 (SD±1.892), ranging from 2 to 12. A group of 27 individuals aged 51–60 had an average score of 10.00 (SD=0.961), ranging from 8 to 12. The average score for two participants over 60 was 8.50, with a standard deviation of ±0.707. Scores were 8–9.

The association of knowledge scores with gender revealed that female participants (*N*=133) had an average knowledge score of 9.22 (standard deviation±1.653), ranging from 4 to 12. The mean score for the 120 male participants was 9.17, with a standard deviation of 2.022. The scores ranged from 2 to 12. The correlation between gender and knowledge score did not reach statistical significance (F=0.049, *P*=0.824), as depicted in Fig. 3.

Analyzing knowledge scores across dental healthcare specializations involves examining data regarding the number of participants (N), average knowledge scores, standard deviation (±SD), and minimum and maximum scores for each specialization. One-way analysis of variance (ANOVA) was performed to assess the statistical significance of variations among the different specializations. The results show that there are statistically significant differences (*P*<0.001) in knowledge scores among the different specializations (ANOVA: F=7.082). The mean knowledge score of the oral pathologists was 10.73 (±SD=0.467), the highest among all the groups. The pedodontists had a mean score of 10.00 (±SD=1.033), the second highest. In contrast, general dentists obtained the lowest average score of 8.48 (±standard deviation=1.701). The analysis is presented in Fig. 4.

The analysis of knowledge scores related to the workplace among dental professionals performed using one-way ANOVA revealed no significant difference (F=1.090; *P*=0.338), indicating that the levels of knowledge among dental professionals were similar regardless of their work settings. More precisely, the average knowledge score of individuals working in government institutions was 9.29

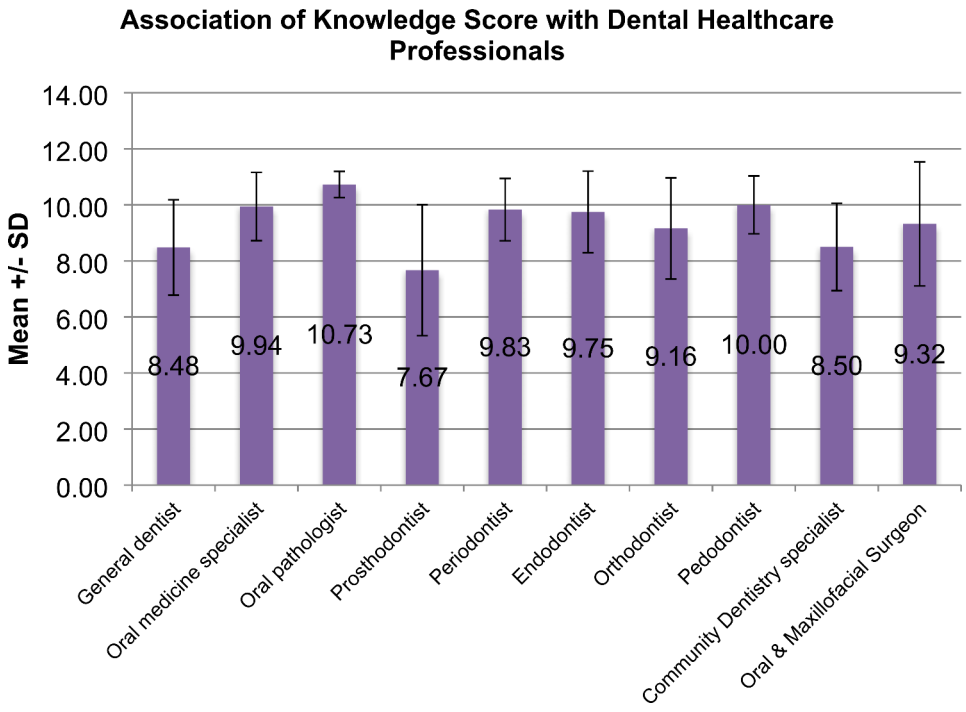

Fig. 4 Depicts the analysis results of knowledge scores across dental health care specializations

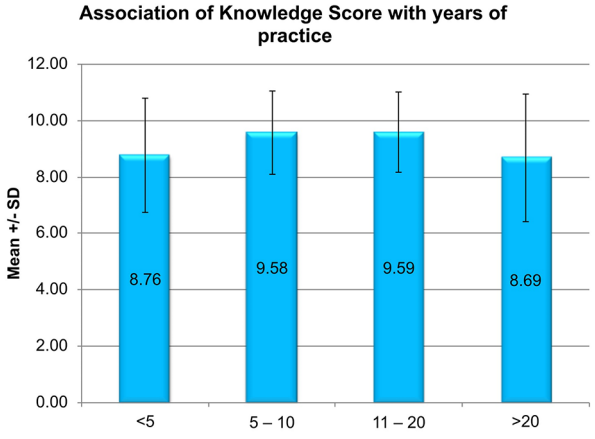

Fig. 5 The correlation between the participants' knowledge score and the number of years of practice

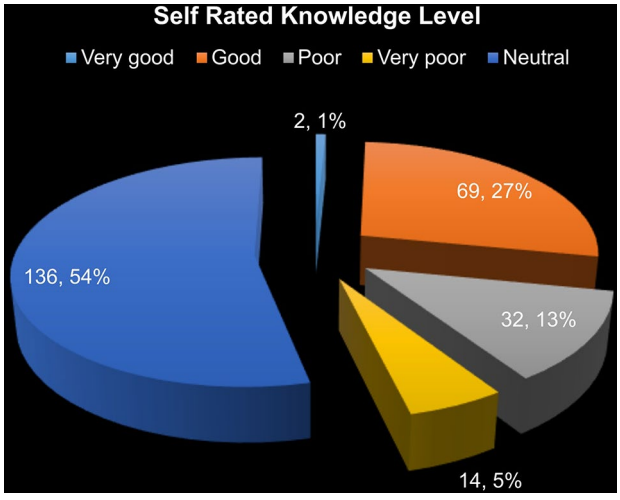

Fig. 6 Represents self-rated knowledge

(1.759), whereas those working in private practices had an average score of 8.93 (1.754). Similarly, dental experts affiliated with educational institutions had an average knowledge score of 9.31 (±1.946).

One-way analysis of variance (ANOVA) was performed to assess the statistical significance of variations in knowledge scores among individuals with different levels of experience. The findings demonstrate a substantial disparity ($P=0.003$) in knowledge scores depending on the duration of professional experience (ANOVA: F=4.755). Participants with 5–10 years of experience had the highest average knowledge score of 9.58 (±standard deviation=1.473). Those with 11–20 years of experience had a slightly lower average score of 9.59 (±standard deviation=1.415). In contrast, individuals with less than 5 years of experience obtained an average score of 8.76 (±standard deviation=2.030), while those with more than 20 years of experience achieved an average score of 8.69 (±standard deviation=2.275). The associations are presented in Fig. 5.

The participants' self-assessed understanding of the oral microbiome, as shown in Fig. 6 was based on their responses to Question 14. To answer this question, dental professionals were asked to evaluate their knowledge and

awareness of the microbiome. The table summarizes the number (N) and percentage (%) of participants who rated their knowledge as very good, good, poor, very poor, or neutral. Among the participants, 0.8% considered their knowledge very good, while 27.3% rated it as good. Additionally, 12.6% of participants regarded their knowledge as poor, and 5.5% regarded it as very poor. Most participants, accounting for 53.8%, remained neutral in their knowledge self-assessment.

Question 14 responses show diverse oral microbiome knowledge. Only 0.8% rated their knowledge "very good," while 27.3% rated it "good." However, 12.6% rated their knowledge "poor" and 5.5% "very poor." Most participants (53.8%) were neutral about oral microbiome knowledge.

Discussion

Our study represents a pioneering effort to assess the level of understanding of the microbiome among dental professionals in Saudi Arabia. This study provides crucial insights into these professionals' knowledge of the oral microbiome, emphasizing its pivotal role in oral healthcare. The findings offer valuable insights into the current state of knowledge among dental professionals in Saudi Arabia, which is essential for developing strategies to promote a balanced oral-gut microbiome axis and enhance overall human health.

Our discussion unfolds within the context of complex demographic factors influencing dental professionals' knowledge levels. Age, gender, specialization, and workplace dynamics are pivotal determinants shaping individuals' access to information, training opportunities, and professional experiences, ultimately affecting their understanding of the oral microbiome. The wide-ranging participants in our study, spanning different age groups, genders, and dental specialities, provided a nuanced understanding of knowledge levels across the professional field, adding a temporal aspect to our investigation.

Furthermore, the study revealed disparities in knowledge scores among various demographic factors. Although age and gender did not significantly impact knowledge levels, noticeable variations were observed among different dental healthcare specializations and years of professional experience. These findings contradict a recent study that showed that individuals under the age of 45 have a less thorough understanding of the microbiome than those over 45 [39]. Participants with 11–20 years of experience exhibited the highest average knowledge score of 9.59 (±1.415). This suggests a positive relationship between years of experience and knowledge levels up to a certain threshold. Nevertheless, individuals with more than 20 years of experience demonstrated a decrease in their knowledge scores. This indicates the importance of ongoing education and updates to prevent the stagnation or erosion of knowledge among experienced professionals. The findings highlight the significance of continuous professional development programmes and lifelong learning initiatives within the dental community to guarantee top-notch oral health care services.

The study findings indicated that dental professionals generally possess a high level of awareness regarding the term microbiome. The results of our study align with previous research that has demonstrated that medical sciences students possess a satisfactory understanding of fundamental microbiome science concepts. [40]. The participants' familiarity with the term "microbiome" and their comprehension of its functions indicate a strong knowledge base within the dental community, consistent with prior research suggesting a growing recognition of the importance of microbial ecosystems concerning health and disease. In a separate study on dental hygienists, 60% of the students indicated high confidence in their understanding of the oral microbiome [41].

Moreover, the study examined the participants' viewpoints regarding the correlation between diet and the microbiome. Question 6 was designed to assess concurrence with the assertion that consuming a greater quantity of unprocessed plant-based foods, such as fruits, vegetables, nuts, seeds, and whole grains, promotes the flourishing of the gut microbiome. The results were encouraging, as 64.4% of participants agreed with the idea, highlighting the awareness among dental professionals of the important role that diet plays in promoting a healthy gut microbiome. Nevertheless, 28.1% of the participants expressed uncertainty, indicating a possible need for additional educational and awareness initiatives. These findings are consistent with increasing research that emphasizes the significance of dietary fibre and plant-based nutrients in promoting a varied and robust gut microbiome, which, in turn, contributes to overall health and well-being [42].

Our study's findings shed light on dental professionals' knowledge and competency regarding the oral microbiome, including aspects related to fiber, probiotics, and prebiotics, and their potential implications for oral health (Q5). Similarly, a study conducted among paediatricians revealed that 57% of paediatric residents and specialists accurately acknowledge the role of probiotics in mitigating the risk of antibiotic-induced diarrhoea [43]. The findings are consistent with the data from the survey conducted on medical sciences majors in the Philippines. Clinical nutrition students scored 42.3%, while public health students scored 29% on questions about the effectiveness of probiotics in treating various health conditions [44]. This finding contrasts with previous findings, highlighting significant gaps in physicians' knowledge regarding probiotic therapies for treating various

illnesses, including allergies and asthma [39]. Nevertheless, both studies emphasize the significance of strengthening educational initiatives to address these knowledge gaps and enhance clinical practices. Increasing healthcare professionals' comprehension of probiotics can enhance clinical practices and improve patient outcomes.

Dysbiotic shifts within the oral microbiome have been linked to OSCC, OLP, and RAU [12, 16, 45, 46]. These changes could undermine the integrity of the oral epithelium and immune responses. The survey data provided intriguing insights into the complex connection between the modified oral microbiota and epithelial barriers in oral mucosal diseases. Notably, 39.9% of respondents agreed on the existence of crosstalk, 34.0% were unsure, and 26.1% disagreed. The disparities in responses highlight the subject's complexities and the need for further investigation. This finding emphasizes the importance of ongoing education and research initiatives to understand better the mechanisms underlying the interaction of the oral microbiota and epithelial barriers in mucosal diseases. Understanding the dynamics of crosstalk is critical for developing effective diagnostic and therapeutic strategies for oral mucosal diseases [47]. By understanding how changes in the oral microbiome affect epithelial barrier integrity and immune responses, researchers and clinicians can develop targeted interventions to slow disease progression and improve patient outcomes.

Recent research indicates that dysbiotic alterations in the oral microbiome may impact overall health, potentially through the development of inflammatory diseases such as RA, obesity, and DM [19, 20, 23, 28, 48, 49]. The oral cavity microbiome is a reservoir for various microbial communities, which influence distant organ systems via diverse mechanisms such as metabolic crosstalk, microbial translocation, and immune modulation [50–52]. Acknowledging these associations shows how crucial oral health is for maintaining overall health and preventing diseases. The survey also investigated perceptions regarding the influence of the composition of the oral microbiome on systemic diseases, such as obesity, Alzheimer's disease, IBD, DM, CVDs, and RA. Surprisingly, a mere 6.7% of participants believed in this correlation. The findings indicate a significant difference in opinions among dental professionals regarding the possible systemic effects of the composition of the oral microbiome. This indicates a need for additional education and awareness campaigns in this field. The complex interaction between the oral microbiome and overall health is a rapidly growing area of study with wide-ranging consequences [35]. This emphasizes the importance of collaboration between dental and medical experts from different fields. By promoting enhanced comprehension and acknowledgement of these interrelationships, healthcare professionals can embrace a comprehensive approach to patient care, effectively managing oral and systemic health issues.

Our research sheds new light on understanding the oral microbiome across various dental specialities in Saudi Arabia. We discovered significant disparities in knowledge scores between these specialities, indicating different levels of comprehension. Oral pathologists had significantly higher knowledge scores, indicating a thorough understanding of microbiome-related concepts in their specialized field. Conversely, prosthodontists had lower scores, indicating potential knowledge gaps in this domain. However, these findings should be interpreted with caution. While our study sheds light on differences in knowledge levels, it is critical to understand that this does not imply that one speciality is superior to another. Individual experiences, ongoing education efforts, and exposure to microbiome-related content potentially influence dental professionals' knowledge levels. Furthermore, our study closes a critical gap in the literature. Although similar studies examining microbiome-related knowledge across dental specialities are rare, our findings provide valuable insights that can guide future research and educational initiatives. Understanding the nuances of oral microbiome knowledge across specialities is critical for fostering a broad understanding within the dental community and improving patient outcomes.

Regarding Question 14, participants were surveyed about their self-assessed understanding of the microbiome and its impact on health and disease. The findings revealed a wide range of perspectives among participants regarding their comprehension of the oral microbiome. Remarkably, only 0.8% of participants regarded their knowledge as "very good," suggesting that a small percentage of individuals had a strong sense of confidence in their understanding. On the other hand, a significant majority (53.8%) remained neutral, indicating a state of uncertainty about their understanding of the oral microbiome. Curiously, conflicting results from a different study indicate a divergence in self-evaluation. Sixty dental hygiene students were surveyed using a Likert scale to measure their confidence levels in bacteriological research. Approximately 60% of the students indicated they were confident in their knowledge [41]. This disparity emphasizes the differences in perceived levels of knowledge among various populations. This finding emphasizes the necessity for further research into the factors influencing self-assessment in understanding the microbiome.

Conclusion

In conclusion, our findings reveal that dental professionals have varying awareness and comprehension of the oral microbiome. Despite widespread awareness, understanding its diversity and implications for oral and systemic

health remains limited. Addressing these gaps through future research and educational interventions is vital, as dental professionals are instrumental in promoting oral health through personalized dietary recommendations, lifestyle adjustments, and hygiene practices. These efforts not only foster a healthy oral microbial community but also improve patient outcomes and advance oral healthcare on both local and global scales. Embracing interdisciplinary collaborations and continuous learning initiatives will enrich microbiome-informed dental practice, fostering innovative approaches to patient care.

Addressing potential confounders and limitations

Despite the comprehensive nature of our study, several potential confounders and limitations must be acknowledged. Using self-reported data raises concerns about potential bias due to social desirability or memory recall, warranting caution in interpreting the results. Additionally, convenience sampling may have introduced sampling bias, limiting the generalizability of our findings. Further research employing more objective metrics and diverse sampling techniques is needed to validate our results. Limitations in questionnaire design and the cross-sectional nature of our study also impose constraints on the interpretation of findings, highlighting the need for future longitudinal research. Finally, unaddressed confounders, such as educational attainment and the availability of continuing education opportunities, may have influenced outcomes, warranting further investigation. Despite these limitations, our study contributes significantly to understanding the oral microbiome among dental professionals in Saudi Arabia.

Abbreviations

OSCC	Oral Squamous Cell Carcinoma
SD	Standard Deviation
OLP	Oral Lichen Planus
RAU	Recurrent Aphthous Ulcer
RA	Rheumatoid Arthritis
IBD	Inflammatory Bowel Disease
DM	Diabetes Mellitus
CVD	Cardiovascular Disease
IQR	Interquartile Range

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

S.P. participated in conceptualization, methodology, and original draft writing; A.S.A. and M.A. performed data collection and interpretation. S.S.K. and A.A.H. participated in data collection and statistical analysis. A.B. and T.D. reviewed and edited the final manuscript. All authors read and approved the final manuscript.

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Data availability

We have uploaded the raw data as an Excel file in the supplementary materials section of the system.

Declarations

Ethics approval and consent to participate

The Jazan University Standing Committee on the Ethics of Scientific Research (REC-45/05/895, HAPO-10-Z-001) approved the study, ensuring ethical guidelines were followed. Informed consent was obtained from all participants before the study began.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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