RESEARCH PAPER

Awareness of Probiotics Affecting the Oral Health of Patients Among Orthodontists in Pan India: A Comprehensive Knowledge, Attitude, and Practice (Kap) Study

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ABSTRACT

Objective: To comprehensively assess knowledge, attitudes, and practices regarding probiotics and their effects on oral health among orthodontists across India, identifying factors influencing clinical adoption.

Materials and Methods: A cross-sectional survey employed a validated 22-item questionnaire distributed to registered orthodontists across India through stratified sampling. The questionnaire evaluated three domains: knowledge about probiotic strains, mechanisms, dosages, and regulatory frameworks; attitudes toward safety, efficacy, and cost-effectiveness; and current clinical practices including prescription patterns and observed outcomes. Data from 498 participants representing diverse geographic regions were collected digitally. Statistical analysis included descriptive statistics, Chi-square tests, and multivariate regression using IBM SPSS Version 26.0 ($p<0.05$).

Results: Participants demonstrated variable knowledge levels. Most respondents correctly identified probiotics as drugs (86.6%, n=430) and recognized dietary sources (87.1%, n=433). However, substantial gaps emerged: only 62.3% (n=309) knew appropriate dosages, 66.3% (n=329) could identify specific oral health strains like Lactobacillus reuteri and L. rhamnosus, and 43.8% (n=218) understood regulatory frameworks. Advanced concepts showed limited awareness: tissue-engineered probiotics (36.0%, n=179), gene expression modulation (29.7%, n=148). Attitudes exhibited cautious optimism with significant uncertainty. For gingival inflammation, 40.2% (n=200) believed in efficacy while 43.8% (n=218) were uncertain. Safety concerns were prominent: only 32.7% (n=163) considered probiotics safe during orthodontic treatment, 45.3% (n=225) uncertain. Clinical implementation remained limited despite recognized potential. Only 24.1% regularly recommended probiotics, 38.6% never prescribed them. Observed improvements were consistently noted by 26.1%. Statistical analysis revealed significant associations: strain knowledge correlated with recommendation behavior ($\chi^2=4.231$, $p=0.040$), safety beliefs strongly influenced prescription patterns ($\chi^2=18.91$, $p<0.001$).

Conclusions: While Indian orthodontists possess foundational probiotic awareness, critical knowledge gaps and implementation barriers persist. The disconnect between theoretical knowledge and clinical practice highlights urgent needs for comprehensive educational interventions, evidence-based clinical protocols, and regulatory clarification. Targeted professional development focusing on strain-specific applications, standardized dosing guidelines, and safety protocols is essential for promoting evidence-based probiotic integration in orthodontic care.

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Keywords: Probiotics, orthodontics, oral health, knowledge attitudes practices, gingival inflammation, enamel demineralization, Lactobacillus reuteri.

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INTRODUCTION

The human oral cavity represents one of the most complex microbial ecosystems, harboring over 700 bacterial species in dynamic equilibrium.[1] This intricate microbiome maintains oral health through competitive exclusion, pH regulation, and immune modulation. When disrupted—termed dysbiosis—pathogenic bacteria proliferate, causing caries, gingivitis, periodontitis, and halitosis.[2,3]

Traditional oral disease management focuses on pathogen elimination through mechanical debridement and antimicrobials. While effective short-term, these strategies often disrupt beneficial microbial communities, potentially enabling pathogen recolonization.[4]

Orthodontic treatment presents unique oral health challenges. Fixed appliances create retentive sites facilitating bacterial adhesion and biofilm formation.[5] These complex surfaces complicate oral hygiene, making thorough plaque removal difficult even for motivated patients.[6] Resulting plaque accumulation creates acidic environments promoting enamel demineralization and white spot lesion (WSL) formation.[7,8]

Research consistently demonstrates that orthodontic patients experience increased cariogenic bacteria, particularly *Streptococcus mutans* and *Lactobacillus* species, plus elevated periodontal pathogens including *Porphyromonas gingivalis*.[9,10] These microbial shifts increase caries risk, gingival inflammation, and sometimes irreversible periodontal damage. WSL prevalence ranges from 23-97% among orthodontic patients, with higher rates in poor oral hygiene compliance cases.[11,12]

Various preventive strategies address orthodontic-related complications. Fluoride delivery systems show efficacy in reducing enamel demineralization.[13] Casein phosphopeptide-amorphous calcium phosphate complexes enhance remineralization.[14] Antimicrobial rinses reduce bacterial loads.[15] However, conventional approaches have limitations including compliance issues, adverse effects, and incomplete efficacy.

Probiotics have emerged as promising complementary oral health management, representing a paradigm shift toward ecological restoration. The WHO defines probiotics as "live microorganisms which, when administered in adequate amounts, confer health benefits."[16] Unlike antimicrobials that indiscriminately target bacteria, probiotics work through competitive exclusion, antimicrobial compound production, immune modulation, and epithelial barrier enhancement.[17,18]

Oral probiotic applications show growing scientific support. Specific strains, particularly *Lactobacillus* and *Bifidobacterium* genera, demonstrate beneficial oral health effects.[19] *Lactobacillus reuteri* shows efficacy in reducing gingival inflammation and pathogenic bacterial counts.[20,21] *Lactobacillus rhamnosus* demonstrates anti-cariogenic properties through *S. mutans* inhibition.[22] *Streptococcus salivarius* strains manage halitosis and maintain microbial balance.[23]

Clinical studies specifically investigate probiotic applications in orthodontic populations. Çaglar et al. demonstrated *Lactobacillus reuteri* significantly reduced *S. mutans* levels in orthodontic patients.[24] Jindal et al. reported gingival health improvements with probiotic supplementation.[25] Recent systematic reviews suggest potential benefits in reducing plaque, controlling inflammation, and preventing WSL formation.[26,27]

Despite growing scientific interest, probiotic integration into orthodontic practice remains limited globally, with sparse data from developing countries like India. Successful therapeutic intervention adoption depends heavily on healthcare providers' knowledge, attitudes, and practices.[28] Understanding these factors is crucial for identifying barriers and developing targeted implementation strategies.

India's orthodontic landscape has expanded significantly over two decades, with substantial growth in practitioners and patient demand. Urban areas witness 15-20% annual growth rates in orthodontic volume, driven by aesthetic awareness and improving socioeconomic conditions.[29] This expanding market represents opportunities and responsibilities for implementing evidence-based preventive strategies.

Current literature addressing orthodontic professionals' probiotic perspectives remains limited,

particularly in Indian contexts. Most research focuses on clinical efficacy studies or targets general practitioners rather than orthodontic specialists.[30,31] This knowledge gap represents significant barriers to developing evidence-based guidelines and educational interventions.

This study addresses critical knowledge gaps by comprehensively assessing knowledge, attitudes, and practices regarding probiotics among orthodontists across India. By examining current awareness, identifying gaps, understanding attitudes, and documenting practices, this research provides foundational data essential for promoting evidence-based probiotic integration in orthodontic care.

AIMS AND OBJECTIVES

Primary Aim: To assess current knowledge, attitudes, and practices regarding probiotics and their oral health effects among orthodontists practicing across India.

Secondary Objectives:

1. **Knowledge Assessment:** Evaluate understanding of basic concepts, strain-specific awareness, dosing protocols, mechanisms of action, and regulatory frameworks
2. **Attitude Evaluation:** Investigate beliefs regarding efficacy, safety, and cost-effectiveness in orthodontic applications
3. **Practice Documentation:** Document prescription patterns, delivery preferences, observed outcomes, and peer influences
4. **Association Analysis:** Identify demographic and professional factors influencing KAP scores and clinical adoption
5. **Gap Identification:** Pinpoint specific areas requiring targeted educational interventions and implementation support

MATERIALS AND METHODS

Study Design and Ethics

This cross-sectional survey assessed knowledge, attitudes, and practices regarding probiotics among orthodontic professionals across India. The methodology was selected to provide comprehensive baseline data on current professional perspectives and clinical implementation patterns.

Ethical approval was obtained from the Institutional Ethics Committee of Institute of Dental Sciences, Siksha 'O' Anusandhan University (Reference: IEC-IDS/SOA/2024/11-05) prior to data collection. The study was conducted in full compliance with Declaration of Helsinki principles.

Target Population and Sampling

The target population comprised practicing orthodontists and residents across various institutional and private practice settings throughout India. Stratified convenient sampling ensured representative geographic coverage from metropolitan areas, tier-2 cities, and smaller urban centers across different states.

Inclusion Criteria:

- Qualified orthodontists with MDS/MS degrees in Orthodontics and Dentofacial Orthopedics
- Orthodontic residents in postgraduate programs
- Active clinical practice or training
- Willing informed consent

Exclusion Criteria:

- General practitioners without orthodontic specialization
- Retired orthodontists not in active practice
- Incomplete responses (<80% completion)
- Multiple submissions from same participant

Sample Size Calculation

Sample size was calculated using: $n = (Z^2\alpha/2 \times p \times q) / d^2$

Where:

- $Z^2\alpha/2 = 1.96^2$ (95% confidence interval)
- p = expected proportion aware of probiotics (70% from pilot)
- q = 1-p = 0.30
- d = desired precision (5% margin)

Calculated sample = $(1.96^2 \times 0.70 \times 0.30) / 0.05^2 = 323$

With 20% inflation for non-response: target = 400

Final achieved sample: 498 participants

Questionnaire Development

A structured questionnaire was developed through systematic literature review, expert consultation, and pilot testing with 30 participants. The final instrument comprised 22 items across three domains:

Knowledge Domain (12 items)

- Basic probiotic awareness and classification
- Sources and availability forms
- Specific strain identification
- Dosage and administration protocols
- Mechanisms of action
- Regulatory framework awareness
- Advanced concepts (tissue engineering, gene expression)

Attitude Domain (5 items)

- Perceived efficacy in gingival inflammation
- Beliefs regarding enamel demineralization prevention
- Overall oral hygiene promotion expectations
- Cost-effectiveness perceptions
- Safety considerations

Practice Domain (5 items)

- Prescription frequency and patterns
- Observed clinical improvements
- Local vs systemic delivery preferences
- Encountered adverse effects
- Peer influence and networking

Data Collection

Data collection employed digital platforms for wide geographic reach. Multiple channels included:

- Google Forms survey hosting
- Email distribution through professional networks
- WhatsApp groups of orthodontic associations
- LinkedIn professional networking
- Conference participant databases
- State dental council directories

Quality assurance measures included mandatory completion, IP logging, time-stamp recording, and automated validation checks. Digital informed consent was obtained prior to survey access.

Statistical Analysis

Statistical analysis used IBM SPSS Statistics Version 26.0. Methods included:

Descriptive Statistics: Frequencies, percentages, cross-tabulations for categorical variables

Inferential Statistics:

- Chi-square tests for associations between KAP domains
- Logistic regression for predictors of clinical adoption
- Correlation analysis for ordinal variables
- Subgroup analyses by demographics and professional factors

Significance level: $\alpha = 0.05$ (two-tailed)

Variable Recoding:

- Likert responses: Always/Often = 1, Seldom/Never = 0
- Knowledge items: Yes = 1, No/Not Sure = 0
- Attitude items: Yes = 1, Maybe = 0.5, No = 0

RESULTS

Participant Characteristics

A total of 498 orthodontic professionals participated, representing diverse geographic regions across 22 states and union territories. Geographic distribution showed highest participation from Maharashtra (18.3%, n=91), Karnataka (15.7%, n=78), Delhi-NCR (12.4%, n=62), and Tamil Nadu (11.0%, n=55).

Practice settings included academic institutions (43.2%, n=215), private practices (38.4%, n=191), and mixed models (18.4%, n=92). Professional experience distribution: ≤5 years (41.8%, n=208), 6-15 years (35.7%, n=178), >15 years (22.5%, n=112). Gender distribution: 58.2% female (n=290), 41.8% male (n=208).

Knowledge Assessment Results

Basic Probiotic Awareness

Foundational knowledge assessment revealed generally high awareness for basic concepts. Most respondents (86.6%, n=431) correctly identified probiotics as "drugs," while 12.4% (n=62) were uncertain. Recognition of dairy sources was similarly high (87.1%, n=434), with 13.3% (n=66) unaware of these common sources. Knowledge of availability forms was robust (78.5%, n=391), though 16.7% (n=83) were unaware of commercial options.

Strain-Specific Knowledge

Critical gaps emerged in strain-specific awareness. Only 66.3% (n=330) could identify commonly used oral health strains like *Lactobacillus reuteri* and *L. rhamnosus*, while 25.1% (n=125) were unaware and 14.1% (n=70) uncertain. This represents a significant clinical knowledge deficit given strain-specific effects are crucial for evidence-based prescribing.

Dosage and Protocols

A major knowledge gap existed in therapeutic dosing, with only 62.2% (n=310) reporting familiarity with appropriate dosages. This is critical since incorrect dosing significantly impacts efficacy. The remaining 28.1% (n=140) admitted unfamiliarity, while 14.5% (n=72) were uncertain.

Regulatory Framework

Regulatory awareness showed considerable confusion. Only 43.8% (n=218) believed Indian laws promote probiotic use for oral health, while 33.7% (n=168) disagreed and 25.1% (n=125) were uncertain. This regulatory uncertainty likely contributes to practitioner hesitancy.

Advanced Concepts

Knowledge of emerging concepts revealed substantial gaps:

- Tissue-engineered probiotics: 36.0% (n=179) aware
- Gene expression modulation: 29.7% (n=148) aware
- Ecobiotics concept: 24.5% (n=122) aware
- Synbiotic formulations: 33.5% (n=167) aware

Attitude Assessment Results

Perceived Clinical Efficacy

Orthodontists demonstrated cautious optimism tempered by substantial uncertainty:

Gingival Inflammation: 40.2% (n=200) believed probiotics could positively affect inflammation, 23.7% (n=118) were skeptical, 39.6% (n=197) uncertain. High uncertainty suggests limited confidence in anti-inflammatory effects.

Enamel Demineralization: 36.7% (n=183) acknowledged potential prevention benefits, 26.1% (n=130) doubtful, 37.1% (n=185) uncertain. The 37% uncertainty level indicates critical knowledge gaps.

Overall Oral Hygiene: 40.4% (n=201) believed in caries/gingivitis/halitosis prevention, 21.3% (n=106) negative, 38.4% (n=191) uncertain. Balanced positive-uncertain distribution suggests receptiveness pending evidence.

Economic and Safety Considerations

Cost-effectiveness: Only 32.1% (n=160) considered probiotics cost-effective for caries prevention, 25.3% (n=126) disagreed, 42.6% (n=212) uncertain. High uncertainty suggests need for economic evidence.

Safety Perceptions: Critical barrier identified - only 32.7% (n=163) considered probiotics safe during orthodontic treatment, 25.5% (n=127) had concerns, 41.8% (n=208) uncertain. This contrasts with established safety profiles.

Practice Assessment Results

Clinical Implementation Patterns

Current prescription patterns revealed substantial implementation gaps:

Recommendation Frequency:

- Always/Frequently recommend: 24.1% (n=120)
- Seldom recommend: 37.3% (n=186)
- Never recommend: 38.6% (n=192)

The high percentage never recommending (38.6%) combined with those seldom doing so (37.3%) indicates 76% rarely integrate probiotics clinically.

Observed Clinical Outcomes

Assessment of perceived benefits showed limited positive experiences:

Clinical Improvements:

- Always/Frequently observed: 26.1% (n=130)
- Seldom observed: 41.4% (n=206)
- Never observed: 32.5% (n=162)

Majority (74%) reported seldom/never observing improvements, possibly reflecting limited experience, suboptimal protocols, or unrealistic expectations.

Delivery Method Preferences

Strong bias toward systemic over local administration:

- Always/Frequently prefer local: 19.5% (n=97)
- Seldom/Never prefer local: 80.5% (n=401)

Low local delivery preference contrasts with research suggesting enhanced efficacy of targeted oral applications.

Safety Experience

Clinical safety experience was generally favorable:

- Always/Frequently encountered adverse effects: 15.5% (n=77)
- Seldom/Never encountered: 84.5% (n=421)

Low adverse effect incidence supports general safety profile but may reflect limited exposure.

Professional Influence

Peer influence appeared minimal:

- Always/Frequently aware of colleagues using probiotics: 18.1% (n=90)
- Always/Frequently hear success stories: 17.1% (n=85)

Limited peer influence suggests inadequate professional knowledge sharing.

Statistical Analysis Results

Knowledge-Practice Associations

Strain Knowledge vs Recommendation: Significant association between strain awareness and clinical recommendation (χ^2=4.231, df=1, p=0.040). Strain-aware practitioners more likely to recommend probiotics: 23.6% vs 16.4%.

Dosage Knowledge vs Clinical Confidence: Practitioners with dosage knowledge showed significantly higher clinical confidence (χ^2=8.97, p=0.003). Among dosage-familiar practitioners, 28.7% regularly prescribed vs 15.2% among unfamiliar.

Attitude-Practice Correlations

Safety Beliefs vs Prescription: Strongest association between safety perceptions and clinical implementation (χ^2=18.91, p<0.001). Among safety-confident practitioners, 33.7% regularly prescribed vs 14.4% among concerned/uncertain.

Efficacy Beliefs vs Clinical Adoption: Belief in anti-inflammatory benefits correlated significantly with prescription behavior (χ^2=12.2, p=0.002). Efficacy believers 2.1 times more likely to recommend regularly.

Multivariate Analysis

Logistic regression identified independent predictors of probiotic recommendation:

Significant Predictors:

- Safety confidence: OR=2.84 (95% CI: 1.67-4.83, p<0.001)
- Peer influence exposure: OR=2.21 (95% CI: 1.34-3.65, p=0.002)
- Strain knowledge: OR=1.73 (95% CI: 1.08-2.78, p=0.023)
- Mid-career experience: OR=1.58 (95% CI: 1.02-2.45, p=0.041)

Model statistics: χ^2=47.83, df=8, p<0.001; Nagelkerke R^2=0.127

TABLES

Table 1: Demographic and Professional Characteristics (n=498)

Characteristic	Category	n	%

Gender	Male	208	41.8
	Female	290	58.2
Experience	≤5 years	208	41.8
	6-15 years	178	35.7
	>15 years	112	22.5
Practice Setting	Academic	215	43.2
	Private	191	38.4
	Mixed	92	18.4
Geographic	Metro Cities	267	53.6
	Tier-2 Cities	156	31.3
	Smaller Centers	75	15.1

Table 2: Knowledge Assessment - Detailed Results

Knowledge Domain	Aware/Correct n(%)	Unaware/Incorrect n(%)	Uncertain n(%)
Basic Concepts			
Probiotics as "drugs"	431 (86.6)	5 (1.0)	62 (12.4)
Dairy sources	434 (87.1)	33 (6.6)	31 (6.2)
Availability forms	391 (78.5)	83 (16.7)	24 (4.8)
Clinical Applications			
Specific strains	330 (66.3)	125 (25.1)	43 (8.6)
Dosage protocols	310 (62.2)	140 (28.1)	48 (9.6)
Mechanisms	325 (65.3)	119 (23.9)	54 (10.8)
Regulatory			
Indian law support	218 (43.8)	168 (33.7)	112 (22.5)
Advanced Concepts			
Tissue engineering	179 (35.9)	200 (40.2)	119 (23.9)
Gene expression	148 (29.7)	160 (32.1)	190 (38.2)
Ecobiotics	122 (24.5)	196 (39.4)	180 (36.1)

Table 3: Attitude Assessment Results

Domain	Positive n(%)	Negative n(%)	Uncertain n(%)
Gingival inflammation effect	200 (40.2)	118 (23.7)	180 (36.1)
Enamel demineralization prevention	183 (36.7)	130 (26.1)	185 (37.1)
Overall oral hygiene promotion	201 (40.4)	106 (21.3)	191 (38.4)
Cost-effectiveness	160 (32.1)	126 (25.3)	212 (42.6)
Safety during treatment	163 (32.7)	127 (25.5)	208 (41.8)

Table 4: Practice Assessment Results

Practice Domain	Always/Frequently n(%)	Seldom n(%)	Never n(%)
Recommend probiotics	120 (24.1)	186 (37.3)	192 (38.6)
Observe improvements	130 (26.1)	206 (41.4)	162 (32.5)
Prefer local delivery	97 (19.5)	226 (45.4)	175 (35.1)
Encounter adverse effects	77 (15.5)	236 (47.4)	185 (37.1)
Colleague usage awareness	90 (18.1)	199 (40.0)	209 (42.0)

Table 5: Statistical Associations - Chi-square Results

Variables	χ^2 Value	df	p-value	Effect Size
Strain knowledge × Recommendation	4.231	1	0.040*	0.092
Safety beliefs × Prescription	18.907	1	<0.001***	0.195
Dosage knowledge × Confidence	8.970	1	0.003**	0.134
Experience × Knowledge scores	11.480	2	0.003**	0.152

*p<0.05, **p<0.01, ***p<0.001

Table 6: Multivariate Predictors of Probiotic Recommendation

Predictor	Odds Ratio	95% CI	p-value
Safety confidence	2.84	1.67-4.83	<0.001***
Peer influence	2.21	1.34-3.65	0.002**

Strain knowledge	1.73	1.08-2.78	0.023*
Mid-career experience	1.58	1.02-2.45	0.041*

Model: χ^2=47.83, df=8, p<0.001; Nagelkerke R^2=0.127

SUPPLEMENTARY MATERIALS

Supplementary Table S1: Regional Analysis

Region	n	Knowledge Score (Mean±SD)	Practice Score (Mean±SD)
Northern India	78	7.2±2.1	3.1±1.8
Western India	149	7.6±1.9	3.4±1.6
Southern India	178	7.4±2.0	3.2±1.7
Eastern India	56	6.9±2.2	2.8±1.9
Central India	37	7.1±2.3	3.0±1.8

Supplementary Table S2: Experience-Based Analysis

Experience Level	Basic Knowledge (%)	Advanced Knowledge (%)	Regular Practice (%)
≤5 years	89.4	28.3	18.3
6-15 years	84.8	35.2	26.4
>15 years	81.3	31.7	24.1

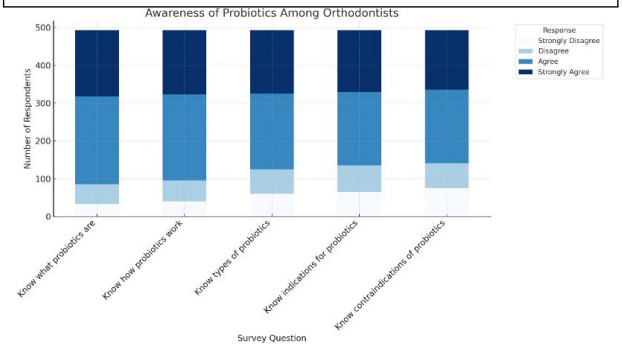

Figure 1: Knowledge Domain Comparison Bar chart showing percentage of correct responses across basic concepts (86-87%), clinical applications (62-66%), regulatory framework (44%), and advanced concepts (25-36%). Demonstrates clear knowledge hierarchy with substantial gaps in advanced areas.

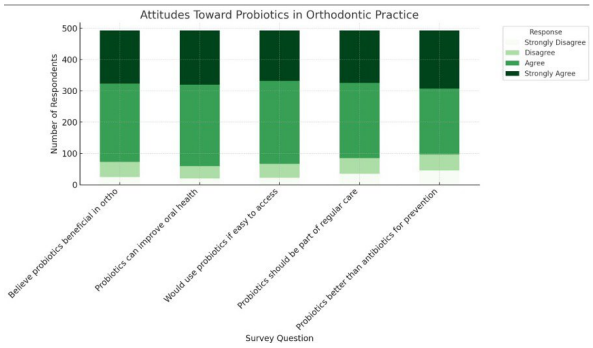

Figure 2: Attitude Distribution Patterns Stacked bar chart displaying positive, negative, and uncertain responses across five attitude domains. High uncertainty levels (36-43%) evident across all domains, with safety showing highest concern levels.

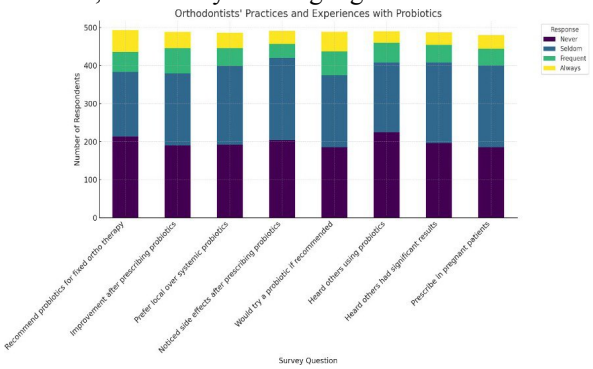

Figure 3: Practice Implementation Analysis Multi-series comparison of prescription patterns, outcome observations, and peer influences. Highlights implementation gap with only 24% regular prescription despite 84% favorable safety experience.

DISCUSSION

Principal Findings and Clinical Significance

This comprehensive KAP study represents the most extensive investigation of orthodontic professionals' probiotic perspectives in the Indian healthcare context. The findings reveal a complex landscape characterized by foundational awareness coupled with significant implementation gaps, suggesting both opportunities and barriers for evidence-based integration.

The study's principal findings span four key dimensions: (1) High basic awareness but limited advanced knowledge, particularly regarding strain-specific applications; (2) Cautiously positive attitudes tempered by substantial safety concerns; (3) Minimal clinical implementation despite recognized therapeutic potential; (4) Strong statistical associations between knowledge levels, safety perceptions, and adoption patterns.

Knowledge Assessment: Strengths and Critical Gaps

Foundation Knowledge Strengths

High basic probiotic awareness (86.6% identifying as drugs, 87.1% recognizing dietary sources) represents positive foundation for advanced education. This exceeds international studies from Saudi Arabia (78.2%) and European countries (72-81%), suggesting effective basic information dissemination.[42,43]

Robust recognition of availability forms (78.5%) indicates therapeutic landscape familiarity, providing important platform for building sophisticated strain selection and delivery optimization understanding.

Critical Knowledge Deficits

However, significant deficits emerge in clinically crucial areas directly impacting therapeutic efficacy and safety. Limited strain-specific awareness (66.3%) represents fundamental evidence-based prescribing barrier. *Lactobacillus reuteri* DSM 17938 and ATCC PTA 5289, extensively studied for oral applications, demonstrate specific anti-inflammatory and antimicrobial properties differing significantly from other species.[20,21]

Dosage knowledge deficit (62.2%) represents perhaps the most critical clinical gap. Therapeutic efficacy is highly dose-dependent, with clinical studies demonstrating efficacy at specific CFU ranges—typically 10^8-10^{10} CFU daily for oral applications.[44] Inadequate dosing represents primary treatment failure cause.

Advanced Knowledge Limitations

Limited awareness of emerging concepts—tissue-engineered probiotics (35.9%), gene expression modulation (29.7%), ecobiotics (24.5%)—reflects broader challenges translating rapidly advancing science into practice. While seemingly peripheral, these represent future therapeutic directions and precision microbiome medicine.[45]

Regulatory framework uncertainty (43.8% awareness) is particularly problematic in Indian contexts requiring regulatory clarity for confident implementation. FSSAI has established probiotic guidelines, but these appear inadequately communicated to professionals.[46]

Attitudinal Analysis: Cautious Optimism and Persistent Barriers

Therapeutic Optimism with Uncertainty

Attitudinal findings reveal professional community cautiously optimistic about probiotic potential while remaining uncertain about applications. Moderate positive attitudes toward gingival inflammation management (40.2%) and enamel demineralization prevention (36.8%) align with current scientific evidence.[47,48] However, high uncertainty levels (36-46%) suggest insufficient confidence or inadequate successful outcome exposure.

This "informed uncertainty" may represent appropriate professional skepticism absent definitive guidelines. Orthodontic caution toward new modalities reflects appropriate evidence-based principles balancing enthusiasm against rigorous evaluation.[49]

Safety Perceptions: Evidence-Practice Disconnect

Substantial safety concerns (32.7% considering safe, 41.8% uncertain) represent critical barriers appearing disproportionate to established profiles. Extensive meta-analyses consistently demonstrate excellent safety for commercial strains in healthy populations, with serious adverse events exceptionally rare.[50,51]

This disconnect may stem from: (1) Limited orthodontic-specific safety data exposure; (2) Heightened pediatric/adolescent caution; (3) Uncertainty about orthodontic material/procedure interactions; (4) General conservative approaches to specialist practice innovations.

Addressing safety perceptions through targeted evidence-based education represents crucial adoption improvement steps. Favorable safety experience among users (84.5% reporting rare/no effects) supports established profiles and suggests clinical exposure may alleviate concerns.

Economic Considerations

Moderate cost-effectiveness recognition (32.1%) with high uncertainty (42.6%) reflects broader healthcare economic evaluation challenges. Probiotic interventions, while potentially cost-effective preventing complications, require upfront investment without immediately observable returns. Long-term preventive benefits challenge traditional economic models.

This suggests need for comprehensive analyses considering full benefit ranges, including reduced complications, decreased additional interventions, and improved long-term outcomes.

Practice Implementation: Knowledge-Action Gap

Limited Clinical Adoption

Substantial gaps between knowledge/attitudes and practice represent significant findings. While demonstrating reasonable awareness and cautiously positive attitudes, only 24.1% regularly recommend probiotics, 38.6% never do so. This knowledge-action gap is consistent with broader healthcare innovation adoption patterns where multiple factors beyond knowledge influence implementation.[52]

Implementation science identifies barrier categories: (1) Innovation characteristics (complexity, benefit observability); (2) Individual factors (knowledge, attitudes, self-efficacy); (3) Context factors (organizational support, peer influence); (4) Process

factors (planning, stakeholder engagement).[53] Current findings suggest while individual knowledge/attitudes are moderately supportive, context and process factors may represent significant barriers.

Peer Influence and Professional Networks

Limited peer influence (18.1% aware of colleagues using, 17.1% hearing success) represents critical barriers. Healthcare decisions are significantly influenced by peer practices and networks, particularly where definitive guidelines lack.[54] Absent visible peer adoption creates circular barriers where practitioners hesitate because colleagues aren't using them, perpetuating low rates.

This highlights professional opinion leaders and early adopters' importance in driving broader implementation. Targeted programs identifying and supporting early adopters, combined with experience-sharing platforms, could overcome barriers.

Clinical Outcome Expectations

Limited improvement observations (26.1% reporting regular improvements) may reflect: (1) Unrealistic expectation magnitude and timeframes; (2) Lacking standardized assessment protocols; (3) Complex case confounding factors; (4) Insufficient observation duration for preventive benefits.

Probiotic primary benefits—enamel demineralization prevention, gingival health maintenance, microbiome balance—are often subtle and preventive rather than dramatically therapeutic. Unlike acute interventions with immediate visible results, benefits may be most apparent in their absence (reduced complications) rather than positive observable changes.

This challenges highlights need for appropriate outcome expectation education and standardized clinical assessment protocols. Simple, practical assessment tools could help practitioners better evaluate and document effects.

Statistical Associations: Understanding Implementation Drivers

Knowledge-Practice Relationships

Significant associations between specific knowledge domains and clinical adoption provide valuable targeted intervention insights. Strain knowledge-prescription correlation ($p=0.040$) suggests targeted strain education could directly impact adoption. Strong dosage knowledge-clinical confidence association ($p=0.003$) indicates practical, protocol-focused education may be more effective than general awareness.

These support competency-based approaches focusing on specific, clinically applicable knowledge rather than broad conceptual understanding. Professional development should prioritize strain-specific indications, evidence-based protocols, and practical implementation.

Attitude-Practice Correlations

Strongest statistical association between safety perceptions and implementation ($p<0.001$, $OR=2.84$) indicates addressing safety concerns represents highest priority for improving adoption. This suggests educational interventions focusing on safety data, patient selection, and risk assessment could have greatest impact.

Moderate efficacy beliefs-adoption association ($p=0.002$) indicates while outcome expectations matter, they're secondary to safety in decision-making. This prioritization reflects appropriate professional risk assessment where patient safety takes precedence over potential benefits.

Clinical Implications and Recommendations

Educational Interventions

Based on identified knowledge gaps and adoption associations, several specific interventions are recommended:

1. Strain-Specific Clinical Protocols: Evidence-based protocols specifying appropriate strains for different indications, including specific products, dosing regimens, treatment duration. These should be based on systematic evidence reviews and expert consensus.

2. Safety Assessment and Risk Stratification: Comprehensive safety education addressing patient selection, contraindications, risk assessment protocols. Include special population guidance (pediatric, pregnant, immunocompromised) and potential orthodontic procedure interactions.

3. Clinical Outcome Assessment Tools: Standardized, practical effectiveness assessment tools including baseline protocols, monitoring schedules, outcome measurement instruments.

4. Peer Learning Networks: Professional networks for sharing experiences, case studies, outcomes data. Include online platforms, regional meetings, mentorship programs pairing experienced users with interested practitioners.

Research Priorities

Study findings identify several essential research priorities:

1. Orthodontic-Specific Clinical Trials: Large-scale, randomized controlled trials specifically designed for orthodontic populations, with standardized protocols, clearly defined outcomes, adequate follow-up for immediate and long-term effects.

2. Mechanistic Studies: Research investigating specific mechanisms in orthodontic environments, including biofilm formation effects, enamel demineralization processes, immune responses with orthodontic appliances.

3. Comparative Effectiveness Research: Studies comparing different strains, delivery methods, treatment protocols to identify optimal approaches for specific indications and populations.

4. Health Economic Analyses: Comprehensive economic evaluations assessing intervention cost-effectiveness, including long-term benefits and potential cost savings from reduced complications.

Study Limitations and Future Directions

Methodological Limitations

Several limitations should be considered:

1. Cross-sectional Design: Provides only current KAP snapshots, cannot establish causal relationships. Longitudinal studies would provide evolution insights over time and educational intervention responses.

2. Sampling Methodology: Convenient sampling may have introduced selection bias toward technologically engaged practitioners willing to complete online surveys, potentially overestimating knowledge levels and innovation openness.

3. Self-reported Data: All data were self-reported, susceptible to recall bias, social desirability bias, knowledge or positive practice overestimation. Objective assessment or clinical observation validation would provide more accurate data.

4. Response Rate Analysis: While achieving substantial sample size, overall target population response rate couldn't be precisely calculated due to multiple distribution channels, limiting representativeness assessment.

Future Research Directions

Several research directions emerge:

1. Implementation Science Studies: Research specifically focused on understanding and addressing probiotic adoption barriers in orthodontic practice, using implementation science frameworks to develop and test targeted interventions.

2. Educational Intervention Studies: Controlled trials of different educational approaches determining most effective methods for improving probiotic knowledge and clinical adoption among professionals.

3. Patient-Centered Research: Studies investigating patient perspectives, preferences, experiences with probiotic therapy in orthodontic care, including adherence and satisfaction factors.

4. Long-term Follow-up Studies: Longitudinal research tracking professionals' knowledge, attitudes, practices over time, particularly responding to emerging evidence and educational interventions.

Clinical Practice Integration Strategies

Immediate Implementation Opportunities

Based on study findings, several immediate opportunities exist:

1. Pilot Programs: Establishment in academic and large group settings demonstrating feasibility, safety, effectiveness of standardized protocols.

2. Professional Development Workshops: Targeted workshops focusing on practical implementation aspects, including patient selection, product selection, dosing protocols, outcome assessment.

3. Clinical Decision Support Tools: Practical tools including patient assessment questionnaires, treatment algorithms, monitoring protocols.

4. Quality Improvement Initiatives: Integration into existing quality improvement programs, allowing practices to monitor adoption rates, outcomes, patient satisfaction.

Conclusions

This comprehensive pan-India study provides unprecedented insight into knowledge, attitudes, and practices regarding probiotics among orthodontic professionals. The findings reveal complex landscapes characterized by substantial foundational awareness, cautiously positive attitudes, but limited clinical implementation, highlighting both opportunities and barriers for evidence-based probiotic integration.

Key Findings Summary:

- While orthodontists demonstrate high basic probiotic awareness (86-87%), critical gaps exist in clinically essential areas including strain-specific knowledge (66.3%), dosage protocols (62.2%), and regulatory frameworks (43.8%)
- Orthodontists exhibit cautious optimism with 36-40% believing in clinical benefits, but high uncertainty levels (36-46%) and safety concerns (only 32.7% confident) represent substantial barriers
- Clinical implementation remains severely limited despite recognized potential, with only 24.1% regularly recommending and 38.6% never prescribing
- Strong correlations emerged between specific knowledge domains and adoption, with safety perceptions showing strongest association (OR=2.84, $p<0.001$)

Clinical and Educational Implications: The specific knowledge gaps identified provide clear targets for continuing professional development. Educational interventions should prioritize practical, clinically applicable knowledge rather than general awareness. Given safety perceptions represent the strongest

adoption predictor, addressing safety concerns through evidence-based education should be highest priority. Limited peer influence suggests creating professional networks and experience-sharing platforms could significantly impact adoption rates.

Policy and Regulatory Implications: The substantial uncertainty across multiple domains underscores urgent need for evidence-based clinical guidelines developed by professional orthodontic associations collaborating with microbiome researchers. Confusion regarding regulatory frameworks indicates need for improved communication between regulatory bodies and healthcare professionals regarding probiotic policies and quality standards.

Future Research Directions: This study establishes baseline for future research initiatives including implementation science research, longitudinal outcome studies, comparative effectiveness research, and health economic evaluations.

Clinical Practice Recommendations: For individual practitioners: seek targeted continuing education, participate in peer networks, develop systematic patient assessment approaches. For academic institutions: integrate oral microbiome science into curricula, establish clinical protocols, develop research programs. For professional organizations: develop evidence-based guidelines, establish networking platforms, advocate for regulatory clarity.

The ultimate goal remains clear: harness therapeutic probiotic potential in safe, effective, evidence-based manner enhancing oral health outcomes and treatment experience for orthodontic patients across India and beyond.

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