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ORIGINAL ARTICLE

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Awareness and Knowledge of Serial Extraction Among General Dentists and Orthodontic Residents in Sana'a City, Yemen

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ABSTRACT

Background: Serial extraction is an interceptive orthodontic approach that guides tooth eruption, promotes spontaneous alignment, and may reduce the complexity of subsequent orthodontic treatment. Evidence on dental practitioners' knowledge and awareness of serial extraction in Yemen is limited. This study assessed knowledge and awareness of serial extraction among general dentists and orthodontic residents in Sana'a City and identified associated demographic and professional factors.

Methods: A cross-sectional study was conducted in Sana'a City, Yemen, from July to August 2025 using paper-based and online questionnaires completed by 379 general dentists and 94 orthodontic residents. Knowledge (10 items) and awareness (11 items) were assessed, and associations were examined using chi-square tests and Pearson's correlation, with statistical significance set at $P < 0.05$.

Results: Among 473 respondents, the mean knowledge and awareness scores were 5.56 ± 2.31 and 8.04 ± 2.44, respectively. Overall, 38.1% had good knowledge, whereas 79.7% had high awareness. Correct responses were least frequent for dental cast analysis (23.7%) and the first extraction in Nance's protocol (37.6%). A large proportion of orthodontic residents had good knowledge (73.4% *vs.* 29.3%) and high awareness (95.7% *vs.* 75.7%) compared with general dentists (both $P < 0.001$). Previous experience with serial extraction was associated with better knowledge ($P = 0.018$) and awareness ($P < 0.001$). Knowledge and awareness scores were positively correlated ($r = 0.502$, $P < 0.001$).

Conclusion: Among the general dentists and orthodontic residents in Sana'a City, awareness of serial extraction is generally high, but gaps remain in diagnostic space analysis and extraction sequencing. These findings suggest a need to strengthen undergraduate teaching, supervised clinical training, continuing professional development, and specialist referral pathways.

Keywords: Awareness ▪ Knowledge ▪ Serial extraction ▪ Orthodontics ▪ Yemen

1. Introduction

Malocclusion and dental crowding contribute substantially to unmet orthodontic treatment needs worldwide. In addition to impairing masticatory function, these conditions can adversely affect periodontal health and psychosocial well-being.[1–3] A population-based study in Yemen has demonstrated substantial orthodontic treatment needs.[4] More than 30% of the children examined had dental crowding, and approximately 20% had dental aesthetic index scores indicating a highly desirable or mandatory need for orthodontic treatment.[4] These findings support the potential role of early

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and interceptive orthodontic interventions in Yemen's public oral health policies.

Serial extraction, defined as the planned sequential removal of selected primary teeth followed by permanent teeth during the mixed-dentition period to manage severe tooth-size-arch-length discrepancies, is a well-established interceptive orthodontic approach that may reduce the complexity and cost of subsequent orthodontic treatment.[5,6] The classical serial-extraction protocol generally involves the sequential extraction of primary canines and primary molars, followed by extraction of first premolars as the permanent dentition erupts. Its principal objectives are to create space, guide the eruption of permanent teeth into more favorable positions, improve spontaneous alignment, and reduce the need for more extensive extractions or complex orthodontic mechanics at a later stage.[6]

Serial extraction requires accurate diagnosis and careful timing during dental development. General dentists' and orthodontic residents' knowledge and awareness may therefore influence patient selection, timely referral, and the quality of care. When appropriately indicated, planned, and timed, serial extraction may simplify subsequent orthodontic treatment and reduce its duration and cost.[6,7]

However, previous surveys have demonstrated variable levels of knowledge and limited clinical confidence regarding serial extraction among dental students, interns, and general dental practitioners, with differences associated with specialty training and clinical exposure.[8–10] Many general practitioners prefer to refer eligible patients to orthodontic specialists rather than undertake serial extraction themselves,[10,11] while contemporary clinical guidance emphasizes careful case selection and appropriate specialist supervision.[12]

In Yemen, malocclusion is common among school-aged children, reflecting a substantial need for orthodontic care.[1–4] Despite this burden, no published local study has assessed dentists' or orthodontic residents' knowledge and awareness of serial extraction or their readiness to refer patients for this intervention. Local evidence could inform undergraduate and postgraduate curricula, continuing professional development programs, and referral pathways. Therefore, this study aimed to assess dentists' and orthodontic residents' awareness and knowledge of the indications, contraindications, timing, and extraction sequence involved in serial extraction in Sana'a City, Yemen. It also aimed to identify sociodemographic and professional factors associated with their awareness and knowledge.

2. Methods

2.1. Study design, setting and participants

A cross-sectional study was conducted in Sana'a City, Yemen, from July to August 2025. Data were collected using both a paper-based questionnaire distributed at dental clinics and universities and an online questionnaire to increase participant reach.

The study included Yemeni general dentists from the public or private sector in Sana'a and orthodontic residents enrolled at Sana'a University and the University of Science and Technology (USTY) in Sana'a. Non-Yemeni dentists or orthodontic residents, individuals who declined to participate, and participants in the pilot study were excluded.

2.2. Sample size and sampling methods

All 107 orthodontic residents enrolled at the two participating universities were approached. For general dentists, the required sample size was calculated using OpenEpi software.[13] Based on an estimated population of 2,500 practicing dentists, a

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95% confidence level, an expected awareness proportion of 50%, and an absolute precision of 5%, the minimum sample size was 333. A census approach was used for orthodontic residents, and convenience sampling was used for general dentists.

2.3. Instrument development and validation

A structured, self-administered questionnaire was developed based on previously published instruments and studies of interceptive orthodontics and serial extraction,[10, 14–18] and adapted to the local context. The introductory page explained the study objectives, confidentiality, voluntary participation, and the use of data for research purposes.

The questionnaire comprised three parts. Part 1 contained 11 questions on demographic and professional characteristics. Part 2 contained 10 single-choice questions assessing knowledge of serial extraction. Part 3 contained 11 awareness statements with response options as "Yes", "No", or "I am not sure".

Knowledge was assessed using 10 dichotomously scored items. Each correct response was assigned a score of 1, whereas each incorrect response was assigned a score of 0. Item scores were summed to generate a total knowledge score ranging from 0 to 10. Based on the total score, participants were categorized as having poor knowledge (0–3 points), moderate knowledge (4–6 points), or good knowledge (7–10 points).

Each awareness item was assigned a score of 1 for a correct response and 0 for an incorrect or "I am not sure" response. For positively worded statements, "Yes" was considered correct, whereas for negatively worded (false) statements, "No" was considered correct. Item scores were summed to generate a total awareness score ranging from 0 to 11. Based on the total score, participants were categorized as having low awareness (0–3 points), moderate awareness (4–7 points), or high awareness (8–11 points).

Content validity was assessed by five experienced orthodontic clinicians and dental researchers from Sana'a University and USTY, who evaluated the questionnaire for clarity, relevance, coverage of the intended constructs, and appropriateness of the response options. The questionnaire was revised in response to their feedback, and the final version was agreed upon in accordance with established content validation principles.[19]

A pilot study was conducted to assess feasibility and internal consistency. Fifty participants (40 general dentists and 10 orthodontic residents) were selected from the accessible population by simple random sampling and were excluded from the final analysis. Cronbach's alpha for the pilot questionnaire was 0.761, suggesting acceptable internal consistency.[20,21]

The reliability of the knowledge and awareness sections was assessed using the split-half method. The items in each section were divided into two parts, and the correlation between the halves was examined. Spearman-Brown and Guttman split-half coefficients were also calculated. The results are presented in Table 1.

Table 1: Split-half reliability statistics for the knowledge and awareness sections of the serial extraction questionnaire

Measure	Knowledge questions	Awareness questions
Cronbach's alpha, Part 1	0.642 (5 items)	0.565 (6 items)
Cronbach's alpha, Part 2	0.288 (5 items)	0.583 (5 items)
Total number of items	10	11
Correlation between forms	0.475	0.603
Spearman–Brown coefficient, equal length	0.644	0.752
Spearman–Brown coefficient, unequal length	0.644	0.753
Guttman split-half coefficient	0.626	0.752

For the knowledge section, Cronbach's alpha was 0.642 for Part 1 and 0.288 for Part 2. The correlation between the two halves was 0.475, with

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a Spearman-Brown coefficient of 0.644 and a Guttman split-half coefficient of 0.626. These findings indicate modest split-half reliability for the knowledge section, although the low alpha value for Part 2 suggests limited internal consistency within that half of the scale (Table 1).

For the awareness section, Cronbach's alpha was 0.565 for Part 1 and 0.583 for Part 2. The correlation between the two halves was 0.603. The Spearman-Brown coefficients were 0.752 and 0.753 for the equal- and unequal-length estimates, respectively, while the Guttman split-half coefficient was 0.752. These findings indicate acceptable split-half reliability for the awareness section (Table 1).

2.4. Data collection

Data were collected using two approaches to maximize participant coverage: paper questionnaires were distributed directly by the researcher to eligible participants at dental clinics and universities. An identical electronic questionnaire, created using Google Forms, was shared through professional WhatsApp groups, Facebook, and other social media platforms to reach eligible participants who were unavailable for direct contact. The final analytic sample comprised 473 participants: 379 general dentists and 94 orthodontic residents.

All participants were informed that completion and submission of the questionnaire constituted informed consent to participate in the study. Table 2 summarizes the study population, questionnaires distributed and returned, exclusions, electronic responses, and the final number of questionnaires included in the analysis. Of the 360 paper questionnaires distributed, 311 were returned, giving a response rate of 86.4%. Of the returned paper questionnaires, 11 (3.5%) were excluded because of incomplete or invalid responses, leaving 300 eligible paper questionnaires for analysis. In addition, 173 complete electronic questionnaires were received. Because all fields in the electronic questionnaire were mandatory, no electronic responses were excluded because of missing data. The final analysis therefore included 473 questionnaires: 300 paper and 173 electronic.

Table 2: Sample distribution to the study population and questionnaires included in the analysis

Group	Population size	Required sample size	Paper questionnaires distributed	Paper questionnaires returned	Paper questionnaires excluded	Paper questionnaires included	Electronic questionnaires included	Total included
General dentists	2,500	333	280	234	7	227	152	379
Orthodontic residents	107	107	80	77	4	73	21	94
Total	**2,607**	**440**	**360**	**311**	**11**	**300**	**173**	**473**

2.5. Data analysis

Data were analyzed using IBM SPSS Statistics, version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the demographic and professional characteristics of participants and the overall levels of knowledge and awareness of serial extraction. Cronbach's alpha was used to assess questionnaire reliability. The split-half method, including Cronbach's alpha, Spearman-Brown, and Guttman coefficients, was used to assess the reliability of the knowledge and awareness sections of the final questionnaire. Chi-square tests were used to assess associations of knowledge and awareness levels with demographic and professional factors. Pearson's correlation coefficient was also used to assess the relationship between knowledge and awareness scores. The significance threshold was set at $P < 0.05$.

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3. Results

3.1. Characteristics of study participants

Of the 473 participants, 53.5% were male. Most were general dentists (80.1%), and 19.9% were orthodontic residents. Academic involvement was reported by 23.3%, and 86.7% were currently engaged in clinical practice. Among practicing dentists, 61.0% worked in the private sector, 26.8% in the public sector, and 12.2% in both sectors. Regarding serial extraction, 44.0% reported previous experience. Most participants (60.9%) graduated between 2021 and 2025, and 62.8% were graduates of private universities (Table 3).

Table 3: Characteristics of study participants (*N* = 473)

Characteristics	*n* (%)
Gender	
Male	253 (**53.5**)
Female	220 (**46.5**)
Professional group	
General dentists	379 (**80.1**)
Orthodontic resident	94 (**19.9**)
Academic involvement	
Yes	110 (**23.3**)
No	363 (**76.7**)
Current clinical practice status	
Practicing	410 (**86.7**)
Not practicing	63 (**13.3**)
Dental practice sector [a]	
Private	250 (**61.0**)
Public	110 (**26.8**)
Both	50 (**12.2**)
Experience with serial extraction	
Yes	208 (**44.0**)
No	265 (**56.0**)
Graduation period	
2005–2020	185 (**39.1**)
2021–2025	288 (**60.9**)
University of graduation	
Public university [b]	176 (**37.2**)
Private university	297 (**62.8**)

[a] Calculated for 410 practicing dentists. [b] Three dentists graduated from public universities abroad.

3.2. Participants' knowledge of serial extraction

Table 4 presents the responses of 473 dentists and orthodontic residents in Sana'a City to questions assessing their knowledge of serial extraction. The highest proportion of correct responses concerned the appropriate radiographic examination (78.9%), followed by recognizing the advantages of serial extraction (73.4%), identifying the teeth involved in the procedure (71.9%), and determining the appropriate age for initiating treatment (70.4%). More than half of the participants correctly identified the contraindications (60.9%) and the appropriate skeletal malocclusion class (56.9%). In contrast, the lowest proportion of correct responses concerned dental cast analysis (23.7%), followed by identifying the first tooth to be extracted according to Nance's method (37.6%) and the usual treatment duration (38.1%). Fewer than half (44.4%) correctly classified serial extraction as an interceptive orthodontic procedure.

3.3. Participants' awareness of serial extraction

Most participants demonstrated high awareness of the basic principles and clinical requirements of serial extraction (Table 5). The importance of careful diagnosis, treatment planning, and patient compliance was recognized by 93.2%; 89.6% recognized the importance of radiographic assessment; 71.9% identified cast analysis as an essential component of treatment planning; and 75.7% acknowledged the importance of appropriate extraction timing. Most also recognized the role of serial extraction in guiding permanent tooth eruption into more favorable positions (83.7%), and 67.9% recognized its potential risks. For the item on the need for subsequent comprehensive orthodontic treatment, 73.6% were classified as having high awareness under the questionnaire's scoring scheme. Furthermore, 78.4% correctly identified midline diastema as an inappropriate indication for serial extraction, while 68.7% recognized that the procedure is not indicated in cases with prosthetic teeth. Awareness was lower regarding the involvement of general dentists in multidisciplinary care (56.9%). For the item on artificial intelligence applications in serial extraction diagnosis, 55.4% were classified as having low awareness.

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Table 4: Knowledge of serial extraction among general dentists and orthodontic residents in Sana'a City, Yemen, 2025 (*N* = 473)

Knowledge question	Response	
	Correct	Incorrect
	n (%)	*n* (%)
Which teeth are extracted during serial extraction?	340 (71.9)	133 (28.1)
How is serial extraction classified as an orthodontic treatment?	210 (44.4)	263 (55.6)
What is the usual duration of serial extraction treatment?	180 (38.1)	293 (61.9)
Which skeletal malocclusion class is suitable for serial extraction?	269 (56.9)	204 (43.1)
At what age is serial extraction best initiated?	333 (70.4)	140 (29.6)
Which type of radiograph is most appropriate for diagnosing serial extraction cases?	373 (78.9)	100 (21.1)
Which dental cast analysis is most appropriate for serial extraction cases?	112 (23.7)	361 (76.3)
In which cases is serial extraction contraindicated?	288 (60.9)	185 (39.1)
What are the advantages of serial extraction?	347 (73.4)	126 (26.6)
According to Nance's serial extraction method, which tooth is extracted first?	178 (37.6)	295 (62.4)

Table 5: Awareness of serial extraction among general dentists and orthodontic residents in Sana'a City, Yemen, 2025 (*N* = 473)

Awareness statement	Statement type	Response	
		Incorrect/uncertain	Correct
		n (%)	*n* (%)
Serial extraction is a multidisciplinary approach that includes general dentists.	True	204 (43.1)	269 (56.9)
Successful serial extraction usually requires careful diagnosis, treatment planning, and patient compliance.	True	32 (6.8)	441 (93.2)
Radiographic assessment is vital for planning and monitoring serial extraction.	True	49 (10.4)	424 (89.6)
Cast analysis is vital for planning and monitoring serial extraction.	True	133 (28.1)	340 (71.9)
The primary goal of serial extraction is to eliminate the need for comprehensive orthodontic treatment later in adolescence.	True	125 (26.4)	348 (73.6)
Serial extraction is indicated for cases with prosthetic teeth.	False	148 (31.3)	325 (68.7)
Serial extraction is a treatment option for cases with midline diastema.	False	102 (21.6)	371 (78.4)
The timing of each extraction step in serial extraction is crucial for achieving the desired outcome.	True	115 (24.3)	358 (75.7)
Serial extraction aims to guide the eruption of the remaining permanent teeth into a more favorable position.	True	77 (16.3)	396 (83.7)
There are potential risks associated with serial extraction, including space closure or unfavorable tooth movement.	True	152 (32.1)	321 (67.9)
There are AI tools/applications used for serial extraction diagnosis.	True	262 (55.4)	211 (44.6)

3.4. Overall knowledge and awareness scores

Among the 473 participants, the mean knowledge score was 5.56 ± 2.31 out of 10, while the mean awareness score was 8.04 ± 2.44 out of 11 (Table 6).

Table 6: Overall knowledge and awareness scores among general dentists and orthodontic residents in Sana'a City, Yemen, 2025 (*N* = 473)

Variable	Mean ± SD	Range
Knowledge score	5.56 ± 2.31	(0–10)
Awareness score	8.04 ± 2.44	(0–11)

SD, standard deviation.

3.5. Levels of knowledge and awareness of serial extraction

Table 7 shows that moderate knowledge was most common (38.5%), followed by good (38.1%) and poor knowledge (23.5%). In contrast, the majority of participants demonstrated high awareness (79.7%), while 15.2% had moderate awareness and 5.1% had low awareness.

Table 7: Distribution of knowledge and awareness levels of serial extraction among Yemeni general dentists and orthodontic residents in Sana'a City, Yemen, 2025 (*N* = 473)

Variables	*n* (%)
Knowledge level	
Poor	111 (**23.5**)
Moderate	182 (**38.5**)
Good	180 (**38.1**)
Awareness level	
Low	24 (**5.1**)
Moderate	72 (**15.2**)
High	377 (**79.7**)

Knowledge score categories: poor (0–3), moderate (4–6), good (7–10). Awareness score categories: low (0–3), moderate (4–7), high (8–11).

3.6. Association between participant characteristics and knowledge levels

Table 8 shows that knowledge level was significantly associated with educational status, graduation period, and previous experience with serial extraction. Orthodontic residents were more frequently classified as having good knowledge than general dentists (73.4% *vs.* 29.3%; *P* <0.001). Knowledge also differed significantly across graduation periods (*P* <0.001), with the highest

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proportion of good knowledge among those graduating in 2005–2010 (80.0%) and the lowest among those graduating in 2021–2025 (31.3%). Participants with previous experience with serial extraction were more frequently classified as having good knowledge than those without such experience (45.2% *vs.* 32.5%; P = 0.018). In contrast, gender, academic involvement, current clinical practice status, and dental practice sector were not significantly associated with knowledge levels (all P >0.05).

Table 8: Associations between participant characteristics and knowledge levels of serial extraction in Sana'a City, Yemen, 2025 (N = 473)

Characteristics	Poor knowledge	Moderate knowledge	Good knowledge	P value	Significant pairwise differences
	n (%)	*n* (%)	*n* (%)		
Gender					
Male	52 (20.6)	100 (39.5)	101 (39.9)	0.270	—
Female	59 (26.8)	82 (37.3)	79 (35.9)		
Professional group					
General dentists	106 (28.0)	162 (42.7)	111 (29.3)	<0.001	Good: residents > general dentists (P_a <0.001) Moderate: general dentists > residents (P_a <0.001) Poor: general dentists > residents (P_a <0.001)
Orthodontic resident	5 (5.3)	20 (21.3)	69 (73.4)		
Academic involvement					
Yes	19 (17.3)	39 (35.5)	52 (47.3)	0.053	—
No	92 (25.3)	143 (39.4)	128 (35.3)		
Current clinical practice status					
Practicing	95 (23.2)	155 (37.8)	160 (39.0)	0.539	—
Not practicing	16 (25.4)	27 (42.9)	20 (31.7)		
Dental practice sector[a]					
Private	54 (21.6)	90 (36.0)	106 (42.4)	0.426	—
Public	28 (25.5)	47 (42.7)	35 (31.8)		
Both	13 (26.0)	18 (36.0)	19 (38.0)		
Experience with serial extraction					
Yes	44 (21.2)	70 (33.7)	94 (45.2)	0.018	Good: yes > no (P_a = 0.017)
No	67 (25.3)	112 (42.3)	86 (32.5)		
Graduation period					
2005–2010	0 (0.0)	4 (20.0)	16 (80.0)	<0.001	Good: 2005–2010 > 2021–2025 (P_a <0.001)
2011–2015	9 (22.5)	10 (25.0)	21 (52.5)		
2016–2020	30 (24.0)	42 (33.6)	53 (42.4)		
2021–2025	72 (25.0)	126 (43.8)	90 (31.3)		

[a] Calculated for 410 practicing dentists. Pairwise comparisons used two-sided Fisher's exact tests, comparing each knowledge level with the other levels combined, with Bonferroni adjustment within each characteristic. P_a = adjusted pairwise P-value. Monte Carlo test was used for variables with small expected cell counts.

3.7. Association between participant characteristics and awareness levels

Table 9 shows that awareness was significantly associated with educational status, dental practice sector, and previous experience with serial extraction. Orthodontic residents were more frequently classified as having high awareness than general dentists (95.7% *vs.* 75.7%; P <0.001). Among practicing dentists, high awareness was reported by 84.0% of those working in both sectors, 82.8% in the private sector, and 76.4% in the public sector (P = 0.018). Participants with previous experience with serial extraction were also more frequently classified as having high awareness than those without such experience (87.5% *vs.* 73.6%; P <0.001). In contrast, gender, graduation period, academic involvement, and current clinical practice status were not significantly associated with awareness (all P >0.05).

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Table 9: Associations between participant characteristics and awareness levels of serial extraction in Sana'a City, Yemen, 2025 (*N* = 473)

Characteristics	Low awareness *n* (%)	Moderate awareness *n* (%)	High awareness *n* (%)	*P* value	Significant pairwise differences
Gender					
Male	12 (4.7)	44 (17.4)	197 (77.9)	0.362	—
Female	12 (5.5)	28 (12.7)	180 (81.8)		
Professional group					
General dentist	24 (6.3)	68 (17.9)	287 (75.7)	<0.001	High: residents > general dentists (P_a < 0.001) Moderate: general dentists > residents (P_a = 0.001)
Orthodontic resident	0 (0.0)	4 (4.3)	90 (95.7)		
Academic involvement					
Yes	3 (2.7)	12 (10.9)	95 (86.4)	0.128	—
No	21 (5.8)	60 (16.5)	282 (77.7)		
Current clinical practice status					
Practicing	18 (4.4)	59 (14.4)	333 (81.2)	0.077	—
Not practicing	6 (9.5)	13 (20.6)	44 (69.8)		
Dental practice sector[a]					
Private	5 (2.0)	38 (15.2)	207 (82.8)	0.018	Low: public > private (P_a = 0.013)
Public	11 (10.0)	15 (13.6)	84 (76.4)		
Both	2 (4.0)	6 (12.0)	42 (84.0)		
Experience with serial extraction					
Yes	5 (2.4)	21 (10.1)	182 (87.5)	<0.001	High: yes > no (P_a < 0.001) Moderate: no > yes (P_a = 0.020)
No	19 (7.2)	51 (19.2)	195 (73.6)		
Graduation period					
2005–2010	0 (0.0)	1 (5.0)	19 (95.0)	0.306	—
2011–2015	3 (7.5)	6 (15.0)	31 (77.5)		
2016–2020	4 (3.2)	15 (12.0)	106 (84.8)		
2021–2025	17 (5.9)	50 (17.4)	221 (76.7)		

[a] Calculated for 410 practicing dentists. Pairwise comparisons used two-sided Fisher's exact tests, comparing each awareness level with the other levels combined, with Bonferroni adjustment within each characteristic. P_a = adjusted pairwise *P*-value. Monte Carlo test was used for variables with small expected cell counts.

3.8. Correlation between overall knowledge and awareness scores

Overall knowledge and awareness scores were moderately and positively correlated (r = 0.502, P <0.001) (Table 10).

Table 10: Correlation between overall knowledge and awareness scores among general dentists and orthodontic residents in Sana'a City, Yemen, 2025

Correlation	Overall knowledge score
Overall awareness score	
Pearson's *r*	0.502**
P	<0.001
N	473

** Statistically significant at *P* <0.001.

4. Discussion

This study found differences between general dentists and orthodontic residents in Sana'a City regarding their knowledge and awareness of serial extraction, an established interceptive orthodontic procedure. The findings also show a gap between participants' awareness of serial extraction and their detailed knowledge of its clinical application. Although most participants demonstrated high awareness of the procedure, 38.1% were classified as having good knowledge. This discrepancy suggests that familiarity with the objectives and general principles of serial extraction does not necessarily correspond to an adequate understanding of its diagnostic and procedural requirements.

Previous studies have also reported differences between recognizing the need for interceptive orthodontic treatment and possessing the detailed knowledge required for appropriate clinical decision-making.[8,10] The moderate positive correlation between knowledge and awareness indicates that participants with greater technical knowledge tended to demonstrate higher awareness. Nevertheless, this association does not establish procedural competence, which requires appropriate clinical judgment, diagnostic skills, and practical experience.

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Participants showed variable knowledge of the basic principles of serial extraction. Most correctly identified the teeth involved (71.9%), but fewer than half (44.4%) classified serial extraction as an interceptive orthodontic procedure. Most participants correctly identified the appropriate age for initiating treatment (70.4%). However, timing also depends on individual dental development, eruption patterns, and crowding severity. These considerations are consistent with other studies.[5,22]

Participants demonstrated awareness of the clinical prerequisites for serial extraction, including comprehensive diagnosis, appropriate treatment planning, radiographic assessment, and patient compliance. Recognition of these requirements is particularly important because serial extraction involves irreversible interventions that may adversely affect occlusal development if performed without appropriate case selection and monitoring. Moreover, many respondents correctly identified mild crowding as a contraindication, reflecting awareness of the importance of selecting appropriate cases and avoiding unnecessary extractions.[23] Nevertheless, correct responses to questionnaire items should not be interpreted as direct evidence of competence in applying these principles to individual patients.

Despite generally high awareness, participants had gaps in their knowledge of diagnostic and procedural aspects of serial extraction. Many respondents did not identify the appropriate dental cast analysis, the Tanaka-Johnston method, which estimates the mesiodistal widths of unerupted canines and premolars and contributes to mixed-dentition space assessment. Accurate space analysis, together with clinical and radiographic evaluation, is essential for estimating tooth-size-arch-length discrepancies and determining whether serial extraction is indicated.

This deficiency is clinically relevant because serial extraction is generally considered for carefully selected patients with substantial crowding, particularly those with Class I malocclusion and marked arch-length deficiency. An arch-length discrepancy of approximately 10 mm or more has been described as a potential indication in selected cases.[24] However, this threshold should not be regarded as an absolute criterion, because treatment decisions must also consider facial profile, skeletal relationships, dental development, and other individual clinical characteristics. Inadequate understanding of space analysis may therefore compromise case selection and increase the risk of inappropriate treatment planning.

Knowledge of the extraction sequence was also limited. Only 37.6% correctly identified the first tooth to be extracted in Nance's protocol. Because the effectiveness of serial extraction depends on the carefully planned timing and sequence of tooth removal,[25] insufficient knowledge of these steps may compromise the intended guidance of eruption and spontaneous alignment. Improper case selection or poorly timed extractions may contribute to undesirable outcomes, including residual spacing, increased overbite, or other occlusal complications.[26] However, the present questionnaire-based study did not evaluate actual treatment outcomes and therefore cannot establish whether these knowledge deficiencies resulted in clinical complications. These findings support strengthening both diagnostic reasoning and procedural knowledge in interceptive orthodontic education.

Orthodontic residents were more frequently classified as having good knowledge and high awareness than general dentists. This difference may reflect additional orthodontic education, more focused clinical training, and greater exposure to

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mixed-dentition management. Jyosthna et al.[9] reported higher knowledge of early orthodontic treatment among pediatric dentists than among general dentists and other professional groups. Al-Dulaimy et al.[8] described pediatric dentists' awareness of orthodontic care and interest in continuing education, although their study did not include a comparison group of general dentists. Differences in participants and questionnaires limit direct comparisons with the present study. Nevertheless, these reports support further attention to education in interceptive orthodontics, particularly the diagnostic and procedural knowledge needed for treatment planning.

The findings also show similarities with those of Nagrale et al.,[10] who investigated knowledge and practices related to interceptive orthodontics among dentists in Pune, India. In their survey, 61.9% of respondents correctly recognized that permanent canines are generally preserved during serial extraction. Likewise, participants in the present study demonstrated familiarity with selected principles of the procedure but showed uncertainty regarding other essential aspects of its implementation. Baskaran et al.[6] also reported that undergraduate dental students were aware of serial extraction, although some remained unclear about its principles. These studies suggest that gaps between theoretical understanding and detailed procedural knowledge may occur across different dental educational and professional settings.

The higher knowledge and awareness levels among orthodontic residents further emphasize the potential contribution of postgraduate education and specialty-oriented clinical exposure. This interpretation is supported by the higher knowledge reported among pediatric dentists in the study by Jyosthna et al.[9] Nevertheless, the cross-sectional design of the present study does not establish that specialty training itself caused the observed difference.

Specialist referral is an important consideration in interpreting these findings, although referral behavior was not assessed in this study. Nagrale et al.[10] reported that approximately 35% of respondents preferred orthodontists to manage interceptive orthodontic problems. Such preferences may reflect recognition of the complexity and irreversible nature of treatment. Clear referral criteria and collaboration between general dentists and orthodontic specialists may help ensure timely evaluation of developing malocclusions, particularly when case selection or treatment planning exceeds a practitioner's expertise.

Previous experience with serial extraction was associated with higher knowledge and awareness levels. This association is consistent with a possible contribution of clinical exposure, but the study cannot determine whether experience improved knowledge or whether more knowledgeable practitioners were more likely to undertake serial extraction. Similarly, Borrie[27] identified insufficient practical knowledge, confidence, and clinical experience as barriers to the provision of interceptive orthodontic care. These observations suggest that improving theoretical knowledge alone may be insufficient and should be complemented by supervised clinical experience, case-based learning, and opportunities to develop diagnostic and treatment-planning skills. Such educational approaches may help practitioners translate theoretical concepts into appropriate clinical decisions.

Graduation period was also significantly associated with knowledge level. Good knowledge was more common among participants who graduated during 2005–2010 than among those who

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graduated during 2021–2025. This difference may be associated with greater cumulative clinical experience, additional professional training, or differences in educational exposure between graduation cohorts. However, because the study did not directly evaluate undergraduate curricula or longitudinal changes in individual knowledge, these explanations remain hypothetical and require further investigation. The observed association is consistent with the potential importance of continuing professional development and accumulated clinical experience.[10]

Knowledge level was not significantly associated with gender. Academic involvement was not significantly associated with either knowledge or awareness. Awareness differed by dental practice sector, but the study did not assess the mechanisms underlying this association.

The present findings and previous studies suggest continuing educational needs in interceptive orthodontics, particularly among non-specialist practitioners. Al-Dulaimy et al.[8] emphasized the interest of pediatric dental specialists in continuing education related to interceptive procedures, including serial extraction. Likewise,Vigneshet al.[28] reported support for early orthodontic intervention among pediatric dentists while identifying the need for improved structured training and continuing education. The knowledge deficiencies identified among general dentists in the present study are consistent with these recommendations and support strengthening undergraduate and postgraduate education in interceptive orthodontics.

The clinical interpretation of these findings should also reflect contemporary recommendations concerning serial extraction. The British Orthodontic Society[12] cautions that the complete serial extraction protocol involving the removal of 12 teeth is seldom recommended and emphasizes the importance of orthodontic assessment before interceptive extractions. This guidance reflects the need for individualized treatment planning rather than routine application of a predetermined extraction sequence. Although serial extraction may reduce crowding and simplify subsequent orthodontic treatment in selected patients, it remains a specialized intervention requiring careful assessment of its potential benefits, limitations, and long-term consequences.

Furthermore, a scoping review reported broadly comparable long-term incisor crowding after serial extraction and early or late premolar extraction in selected patients.[29] These findings reinforce the importance of considering alternative interceptive or comprehensive orthodontic approaches, including leeway-space preservation, space maintenance, and appropriately indicated orthodontic expansion. The choice of intervention should be based on individual diagnostic findings, anticipated growth and development, and the available evidence rather than on crowding severity alone.

Given the complexity of serial extraction, uncertainty regarding specific indications and extraction protocols further supports the need for accessible clinical guidance and appropriate specialist consultation. The recommendations of the British Orthodontic Society[12] emphasize obtaining orthodontic advice before undertaking interceptive extractions when specialist assessment is indicated. In the Yemeni context, incorporating such principles into locally applicable clinical protocols may improve consistency in case selection, referral decisions, and treatment planning.

Another finding was the limited familiarity with artificial intelligence (AI) applications relevant to orthodontic diagnosis and treatment planning.

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More than half of the participants were classified as having low awareness on the item concerning AI tools for serial extraction diagnosis. A survey in Pakistan also reported limited use of AI tools in orthodontic extraction planning.[30] Although AI-assisted approaches are increasingly being investigated for orthodontic assessment, diagnosis, and treatment planning,[18] their integration into routine clinical practice may be influenced by the availability of digital infrastructure, professional training, financial resources, and institutional support.

In resource-constrained settings such as Yemen, these factors may contribute to limited familiarity with emerging technologies. However, the present study did not directly investigate the causes of limited AI awareness or assess the availability, diagnostic accuracy, or clinical effectiveness of AI-based tools. Accordingly, the findings should be interpreted as indicating a potential need for greater exposure to digital orthodontic technologies rather than demonstrating a direct effect on treatment outcomes.

Overall, the findings indicate a need for educational strategies that place greater emphasis on practical diagnostic reasoning, treatment planning, and appropriate selection among available interceptive orthodontic interventions. In particular, case-based teaching should address space analysis, extraction sequencing, timing, contraindications, treatment alternatives, and recognition of situations requiring specialist referral.

Greater collaboration among general dentists, pediatric dentists, and orthodontists may facilitate early identification of developing malocclusions and timely specialist evaluation. Strengthening referral pathways and continuing professional education are also consistent with previous recommendations for improving access to appropriate interceptive orthodontic care.[28]

Several limitations should be considered when interpreting the findings of this study. The cross-sectional design permits identification of associations but does not establish causal relationships between knowledge, awareness, professional training, and other participant characteristics. In addition, convenience sampling was used to recruit general dentists, introducing a risk of selection bias and limiting the generalizability of the findings to the wider population of general dentists in Yemen. The study was restricted to Sana'a City, and its findings may not be representative of practitioners in other Yemeni governorates or rural settings, where educational opportunities and clinical resources may differ. Knowledge and awareness were assessed through questionnaire responses rather than direct observation of clinical practice. Consequently, responses may have been influenced by recall, response, or social desirability biases and may not accurately reflect participants' practical clinical competence. The reliability assessment identified low internal consistency in one half of the knowledge scale, raising concerns about the reliability of that subset of items and the precision of the resulting knowledge measurements. This limitation should be considered when interpreting knowledge scores and statistical comparisons. Finally, the questionnaire assessed cognitive knowledge and awareness but did not evaluate practical diagnostic skills, actual treatment decisions, referral behavior, or patient outcomes. Future investigations using validated instruments and objective clinical assessments are therefore needed to determine the extent to which questionnaire-based knowledge corresponds to clinical performance.

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5. Conclusion

The findings reveal a gap between high awareness and moderate knowledge of serial extraction, particularly in diagnostic space analysis and extraction sequencing. Orthodontic residents demonstrate greater knowledge and awareness than general dentists, while earlier graduation and greater clinical exposure are associated with higher knowledge levels. These findings emphasize the need to strengthen undergraduate education, clinical training, and continuing professional development, focusing on evidence-based diagnosis, treatment planning, and specialist referral to improve interceptive orthodontic care.

Ethical approval

Ethical approval was obtained from the USTY Research Ethics Committee (Approval No. 1447/0088/UREC/UST). All participants were informed about the study prior to participation, and informed consent was obtained either in writing or electronically. For participants providing electronic consent, completion and submission of the questionnaire constituted informed consent to participate in the study.

Conflict of interest

The authors declare no conflicts of interest.

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Supplementary Material

Questionnaire

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