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ORIGINAL ARTICLE

# Expert consensus on Didactic Clinical Skills Development for orthodontic curricula

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## Abstract

**Purpose/objective:** Competence is expected of each beginning dentist and orthodontist. However, the broad definition of competence presents a challenge to academic programs in identifying the level of cognition for students to achieve competence. This study aimed to determine the Didactic Clinical Skills Development curriculum content and competency in predoctoral and advanced education orthodontic programs.

**Method:** A modified Delphi method with a consensus threshold of 70% was employed using an expert panel of academic orthodontists.

**Results:** Round One ($n = 26$) identified that all topics proposed by a focus group were necessary, except for predoctoral *Appliances*, which was at 65%. Round Two ($n = 23$) included subtopics of *Appliances* to confirm the lack of consensus, plus subtopics of all the other topics and the level of cognition required for each subtopic. The expert panel reached a consensus that all 24 subtopics, hence all topics, were necessary. In Round Three, subtopic responses in Round Two were assigned a value between 1 (*remember*) and 6 (*create*) to generate a hierarchical level-of-learning scale. Mean values were calculated for each subtopic response. For all subtopics, the mean level of cognition for predoctoral education was at *understand*; for advanced education, it was at *evaluate*.

**Conclusion:** This consensus suggests that, to be deemed competent, beginning dentists must learn these topics and subtopics in the cognitive domain of *understand*, and beginning orthodontists in the cognitive domain of *evaluate*. This study showed an expert consensus on Didactic Clinical Skills Development orthodontic curriculum content and a panorama of educational objectives that could be used as a template for curriculum design.

KEYWORDS
clinical skills/topics, curriculum development/evaluation, Delphi technique, dental education, orthodontics

  

## 1 | INTRODUCTION

Predoctoral and advanced dental education lays the foundational knowledge and skills for future dentists and specialists. The Commission on Dental Accreditation (CODA)[1,2] and the Commission on Dental Accreditation of Canada (CDAC)[3,4] mandate that a graduating dental student or orthodontic resident demonstrate competence, which CODA defined as "knowledge, skills and values necessary to begin independent, unsupervised (specialty) practice."[1,2] This broad definition presents a challenge to academic programs in identifying the levels of cognition required in predoctoral and advanced education orthodontic curricula for learners to reach competence.[5] Resultantly, didactic content and essential clinical experience vary among programs, and, presumably, so do competencies and outcomes assessment.[5–8]

In 1993, the "Curriculum Guidelines for Orthodontics"[9] (henceforth referred to as 1993 Guidelines) for predoctoral education was published by the American Dental Education Association (ADEA), then known as the American Association of Dental Schools. The 1993 Guidelines outlined the predoctoral orthodontic curriculum content in three levels: (*level 1*) Growth and Development; (*level 2*) Preclinical Orthodontics; and (*level 3*) Clinical Experience.[9] The technological and scientific strides in the past 27 years demand an update of the 1993 Guidelines to meet the challenges of modern dental practice.[5]

In 2009, the World Federation of Orthodontists (WFO) issued guidelines[10] (henceforth referred to as WFO Guidelines) to be used by advanced education programs in orthodontics and related institutions around the world to "measure their respective curriculum against a worldwide standard."[10] These guidelines included educational topics and outcomes assessment among other items and conditions essential for a graduate program in orthodontics.[10] However, the WFO Guidelines did not specify in their recommended curriculum the level of cognition a learner must achieve to be deemed competent.

Bloom's "Taxonomy of educational objectives: the classification of educational goals" was established as a framework for identifying the specific meaning of broad goals for what educators intend students to learn in a particular course work.[11] Krathwohl revised Bloom's taxonomy and classified cognition in six hierarchical levels: *remember, understand, apply, analyze, evaluate*, and *create*[11] (henceforth referred to as revised Bloom's taxonomy). When identified, the level of learning necessary for learner competence will lead to educational objectives, learning activities and assessments that are congruous, despite instructor biases and different modes and hours of instruction.[5,11]

The overarching goal of our investigation is to determine predoctoral and advanced orthodontic education curriculum content in three levels using the 1993 Guidelines[9] as our model. Previously, the topics and subtopics and the level of cognition necessary for learner competence in (*level 1*) Growth and Development were identified by a panel of expert orthodontic educators through a modified Delphi method.[5] The present study, which is the second of a three-part project, addressed the curricular needs in (*level 2*) Preclinical Orthodontics, which is taught didactically to provide the prerequisite theoretical knowledge for patient care. Because didactic courses in orthodontics may be given in conjunction with (*level 3*) Clinical Experience, the term "Didactic Clinical Skills Development" for *level 2* was adopted to distinguish it from essential clinical experience. The present study aimed to identify the Didactic Clinical Skills Development curriculum content in predoctoral and advanced orthodontic education programs, and to determine the level of cognition necessary for this curriculum content by consensus among expert orthodontic educators.

## 2 | METHOD

This study was approved by the University of Missouri-Kansas City (UMKC) Institutional Review Board (UMKC IRB Protocol 2019822). To generate consensus among participants, a modified Delphi method was utilized as described previously.[5] A formal consensus process, the Delphi method aims to approximate the objective truth by using iterations.[12,13]

### 2.1 | Development of an initial list of topics and subtopics

A focus group, composed of five full-time faculty members from three orthodontic programs in the United States—the University of Missouri-Kansas City, Oregon Health & Science University, and the University of Iowa—was formed to develop an initial list of topics and subtopics. The focus group members upheld teaching responsibilities in predoctoral and advanced education Didactic Clinical Skills Development courses as Course Directors and/or Instructors and had an average, combined experience as orthodontists for 25 years (minimum 4 years, maximum 44 years) and as orthodontic educators for 22 years (minimum 4 years, maximum 26 years).

The topics outlined in (*level 2*) Preclinical Orthodontics of the 1993 Guidelines[9] were realigned to develop an initial list of topics and subtopics for Didactic Clinical Skills Development (Table 1). The focus group categorized *Space analysis* and *Tooth-size analysis* under a new topic, *Dentition Analyses. Classification of*

**TABLE 1** Realignment of the 1993 "Curriculum Guidelines for Orthodontics."[9] Topics of the 1993 Guidelines that were carried over, categorized under a new topic, or combined as a new topic

| Didactic Clinical Skills Development topics | 1993 Guidelines topics |
|---|---|
| 1. Production of appropriate diagnostic records[l] | Production of appropriate diagnostic records[l]* |
| 2. Dentition analyses | Space analysis*<br>Tooth-size analysis* |
| 3. Classification, etiology, and epidemiology of malocclusion | Classification of malocclusion*<br>Etiology of malocclusion*<br>Epidemiology of malocclusion* |
| 4. Relationship of morphology to malocclusion | Cephalometric evaluation of skeletal soft tissue, and dental relationships *<br>Relationship of facial morphology to malocclusion * |
| 5. Management of malocclusion | Differentiation of patients with isolated, uncomplicated problems from those with complex problems*<br>Treatment planning for limited orthodontic procedures* |
| 6. Tooth movement | Biology of tooth movement[§]<br>Types of tooth movement*<br>Principles of anchorage*<br>Characteristics of force delivery systems* |
| 7. Appliances | Principles of appliance design*<br>Fabrication of orthodontic appliances and laboratory work authorizations * |

[l]Topic carried over from the 1993 Guidelines.[9]
*Topic derived from (*level 2*) Preclinical Orthodontics of the 1993 Guidelines.[9]
[§]Topic derived from (*level 1*) Growth and Development of the 1993 Guidelines.[9]

*malocclusion*, *Etiology of malocclusion*, and *Epidemiology of malocclusion* were consolidated into one topic. *Differentiation of patients with isolated, uncomplicated problems from those with complex problems*, and *Treatment planning for limited orthodontic procedures* were categorized under a new topic, *Management of Malocclusion*. *Cephalometric evaluation of skeletal soft tissue and dental relationships* and *Relationship of facial morphology to malocclusion* were grouped into the topic *Relationship of Morphology to Malocclusion*. The topic *Biology of tooth movement* listed in 1993 Guidelines' (*level 1*) Growth and Development[5,9] was combined with *Types of tooth movement*, *Principles of anchorage*, and *Characteristics of force delivery systems* under the category of a new topic, *Tooth Movement*. *Principles of appliance design* and *Fabrication of orthodontic appliances and laboratory work authorizations* were incorporated under the new topic *Appliances*.

Further development of an initial list of topics and subtopics was guided by comparing the 1993 Guidelines at the level of Didactic Clinical Skills Development with several sources. The principal investigator compared the 1993 Guidelines with contents of UMKC 2017 and 2018 predoctoral and advanced orthodontic education Didactic Clinical Skills Development courses. Also consulted were the reading list and subject areas for the written examination administered by the American Board of Orthodontics (ABO) as part of the board certification process,[16] the CODA Accreditation Standards for Advanced Specialty Education Programs in Orthodontics and Dentofacial Orthopedics[2] (henceforth referred to as CODA Standards for Orthodontic Programs), the CDAC Accreditation Requirements for Orthodontics and Dentofacial Orthopedics Programs,[4] the WFO Guidelines,[10] and The Erasmus Programme for Postgraduate Education in Orthodontics in Europe: an Update of the Guidelines[14] (henceforth referred to as Erasmus Guidelines). To identify additional topics and subtopics, a literature search in PubMed was done using the following MeSH terms: clinical, skills, and orthodontics; and, clinical, treatment, and orthodontics. The search was limited to review articles in English on human species published between January 1, 1993 and April 19, 2019. Both searches yielded 880 articles with overlapping results in the MeSH searches. Based on the titles, the articles were evaluated for whether or not they pertained to orthodontic clinical skills and/or treatment. If a title did not appear to refer to clinical skills in orthodontics, the abstract was read. The titles and abstracts that pertained to clinical skills in orthodontics were categorized thematically as topics or subtopics of the realigned Didactic Clinical Skills Development curricula. Using the abovementioned comparisons and search, the focus group drafted an initial list of seven topics at the predoctoral level and eight topics at the advanced level (Table 2), and a total of 24 subtopics for both levels

**TABLE 2** Round One expert panel consensus. Percentage of participants ($n = 26$) who considered a topic necessary for Didactic Clinical Skills Development curricula for predoctoral and advanced education programs

| Topic | Predoctoral (%) | Advanced (%) |
|---|---|---|
| 1. Production of Appropriate Diagnostic Records | 92.31 | 96.15 |
| 2. Dentition Analyses | 96.15 | 96.15 |
| 3. Classification, Etiology, and Epidemiology of Malocclusion | 88.46 | 96.15 |
| 4. Management of Malocclusion | 92.31 | 96.15 |
| 5. Relationship of Morphology to Malocclusion | 88.46 | 96.15 |
| 6. Tooth Movement | 88.46 | 96.15 |
| 7. Appliances | 65.38 | 96.15 |
| 8. Supporting Curricula | NA* | 92.31 |

Abbreviation: NA, not applicable.
Contents of the Supporting Curricula are advanced level courses, hence are not applicable to the predoctoral education program.

(Table 3). The eighth topic, *Supporting Curricula*, for advanced education was derived from CODA Standards for Orthodontic Programs.[2] *Supporting Curricula* include *Biostatistics*, *Jurisprudence*, and other courses that may not pertain directly to orthodontic care but are necessary to support the development of a well-rounded orthodontist.

The Round One survey was created based on the initial list of topics generated by the focus group. The Round Two survey was constructed based on the subtopics under each topic. Questionnaire development and pilot-testing with UMKC Department of Orthodontics and Dentofacial Orthopedics part-time faculty members were performed as described previously.[5]

## 2.2 | Expert panel

In the Delphi method, iterations of questionnaires are sent to an expert panel to combine opinions and produce a group consensus.[12,13] The expert panel was composed of academic orthodontists whose recruitment was described previously[5] and who met the following inclusion criteria:

- full-time faculty member involved with teaching and research and/or administration in a CODA- or CDAC-accredited dental school;
- five years or more of teaching and clinical orthodontic experience;
- current or previous ABO certification and/or Royal College of Dentists of Canada fellowship;
- published in a peer-reviewed journal, given a professional presentation and/or received one award within the past 3 years;
- current active involvement in an organization that upholds the best interests of dental and orthodontic education.

## 2.3 | Rounds of the modified Delphi method

In Round One, the expert panel nominees, who met the inclusion criteria, received an invitation to complete an anonymized online survey. Participants were asked to mark each topic as "necessary" or "unnecessary" for predoctoral and advanced education Didactic Clinical Skills Development curricula. A consensus threshold of ≥70% was used to consider a topic necessary to predoctoral or advanced education orthodontic curricula. As described previously,[5] participants were asked to indicate a reason for marking a topic "unnecessary" and to include additional topics not found in the initial list.

Round Two aimed to determine the subtopics within each of the topics that were considered as necessary in Round One. The expert panel nominees were sent an invitation to participate in the Round Two survey. The consensus was deemed reached when ≥70% of the participants marked a level of cognition necessary for learner competence for each subtopic. Additionally, the participants were asked to mark "unnecessary" if a subtopic was deemed not necessary to the predoctoral and advanced education Didactic Clinical Skills Development curricula. As in Round One, participants, who marked a subtopic "unnecessary," were asked to provide a reason. Also, they were requested to recommend any additional subtopics and the corresponding revised Bloom's level of cognition alongside each suggested subtopic. In a free-form format, the participants were asked for their opinion on the future of orthodontic education in the next decade.

Round Three consisted of data analyses and interpretation of the Round Two survey results. As described previously,[5] a table that indicated the distribution of responses according to the revised Bloom's level of cognition was created (Table 3). The six hierarchical levels of cognition, namely *remember, understand, apply, analyze,*

**TABLE 3** Round Two expert panel consensus. Subtopics are followed by descriptions in parentheses. Data presented are percentage (%) of participants ($n = 23$) who considered a subtopic necessary, and the mean scores and mean revised Bloom's levels of cognition for each subtopic for Didactic Clinical Skills Development curricula for predoctoral and advanced education programs

| | Predoctoral | | | Advanced | | |
|---|---|---|---|---|---|---|
| **Topic/subtopic** | **%** | **Mean** | **Mean level of cognition[‡]** | **%** | **Mean** | **Mean level of cognition[‡]** |
| **1. Production of Appropriate Diagnostic rRecords** | | | | | | |
| 1a. *Patient history taking and clinical exam* (may include dental and medical, including psychological aspects relevant to orthodontic care) | 100 | 3.61 | Apply | 100 | 5.26 | Evaluate |
| 1b. *Models* (may include analog and digital) | 100 | 3.43 | Apply | 100 | 5.04 | Evaluate |
| 1c. *Radiographic imaging* (may include CBCT, panoramic, cephalometric, and other views) | 100 | 3.22 | Apply | 100 | 5.13 | Evaluate |
| 1d. *Extraoral and intraoral photography* (acquired in-person or remotely) | 100 | 3.52 | Apply | 100 | 5.13 | Evaluate |
| 1e. *Videography* | 74 | 2.71 | Understand | 91 | 4.33 | Analyze |
| **2. Dentition Analyses** | | | | | | |
| 2a. *Primary, mixed, and permanent dentition* (may include space analysis and tooth-size analysis) | 100 | 3.09 | Apply | 100 | 5.17 | Evaluate |
| 2b. *Diagnostic set-up* | 91 | 2.57 | Understand | 100 | 4.96 | Analyze |
| **3. Classification, Etiology, and Epidemiology of Malocclusion** | | | | | | |
| 3a. *Classification of malocclusion* (may include Angle, Sicher, Scott, and others) | 100 | 3.48 | Apply | 100 | 5.17 | Evaluate |
| 3b. *Classification according to severity* (may include isolated and uncomplicated problems, complicated problems, and indices used to assess case severity) | 100 | 3.17 | Apply | 100 | 5.13 | Evaluate |
| 3c. *Etiology of malocclusion* (may include genetic and environmental) | 100 | 2.83 | Understand | 100 | 5.09 | Evaluate |
| 3d. *Epidemiology of malocclusion* | 100 | 2.61 | Understand | 100 | 4.83 | Analyze |
| **4. Relationship of Morphology to Malocclusion** | | | | | | |
| 4a. *Skeletal, facial and dental analyses* (may include cephalometric, photographic, CBCT analyses) | 100 | 2.74 | Understand | 100 | 5.26 | Evaluate |
| 4b. *Visual treatment objectives* | 100 | 2.45 | Understand | 100 | 5.26 | Evaluate |
| **5. Management of Malocclusion** | | | | | | |
| 5a. *Isolated and uncomplicated cases limited to dental in origin* (management includes no treatment, in-person or remote monitoring, interception, treatment, and referral) | 100 | 3.17 | Apply | 100 | 5.22 | Evaluate |
| 5b. *Moderate cases, such as those involving skeletal discrepancy* (management includes no treatment, in-person or remote monitoring, interception, treatment, and referral) | 91 | 2.48 | Understand | 100 | 5.13 | Evaluate |
| 5c. *Complex cases requiring interdisciplinary care, such as TMD, orthognathic, and periodontally involved cases* (management includes no treatment, in-person or remote monitoring, interception, treatment, and referral) | 91 | 2.19 | Understand | 100 | 5.04 | Evaluate |
| 5d. *Assessment of treatment progress and outcome of treatment* (maybe in-person or virtual when applicable; may include oral hygiene, root resorption and other complications of orthodontic treatment, the outcome of sleep apnea appliances, and superimposition and cast-radiographic evaluation) | 91 | 2.52 | Understand | 100 | 5.17 | Evaluate |

(Continues)

**TABLE 3** (Continued)

| Topic/subtopic | Predoctoral % | Predoctoral Mean | Predoctoral Mean level of cognition[1] | Advanced % | Advanced Mean | Advanced Mean level of cognition[1] |
|---|---|---|---|---|---|---|
| 5e. *Evidence-based decision-making* | 100 | 2.65 | Understand | 100 | 5.09 | Evaluate |
| 5f. *Patient management* (may include patient compliance, cultural competence and ethics) | 100 | 2.96 | Understand | 100 | 5.22 | Evaluate |
| **6. Tooth Movement** | | | | | | |
| 6a. *Biology of tooth movement* | 100 | 2.39 | Understand | 100 | 4.87 | Analyze |
| 6b. *Principles and types of anchorage* (may include dental and skeletal anchorage, including temporary anchorage device) | 100 | 2.30 | Understand | 100 | 5.22 | Evaluate |
| 6c. *Biomechanics* (may include types of tooth movement, characteristics of force delivery systems, vector addition, and virtual tooth movement) | 96 | 2.39 | Understand | 100 | 5.35 | Evaluate |
| **7. Appliances** | | | | | | |
| 7a. *Principles and application of appliance design* (may include fixed and removable appliances, aligners, lingual arches, sleep apnea appliances, and auxiliary appliances) | 96 | 2.65 | Understand | 100 | 5.35 | Evaluate |
| 7b. *Orthodontic materials and appliance fabrication* (may include wire bending, retainer, clear aligner, and analog and digital appliances) | 91 | 2.70 | Understand | 100 | 5.22 | Evaluate |

[1] Corresponding level of cognition of the mean scores: 2.00–2.99 *Understand*; 3.00–3.99 *Apply*; 4.00–4.99 *Analyze*; and 5.00–5.99 *Evaluate*.

*evaluate*, and *create*, were assigned scores 1–6, respectively. To create average mean ratings, the numerical scores designated for each subtopic were used. Responses that marked a subtopic "unnecessary" were considered missing, thus were not included in the mean ratings. To determine the mean level of cognition for each subtopic, the mean ratings were used.

## 3 | RESULTS

Expert panel recruitment resulted in 48 nominations of academic orthodontists from 35 orthodontic programs across the United States and Canada. Twenty-six expert orthodontic educators out of the 48 expert panel nominees, who met the inclusion criteria, participated in Round One that determined the topics necessary for predoctoral and advanced education Didactic Clinical Skills Development curricula. The expert panel arrived at a consensus that six out of seven topics were necessary for the predoctoral Didactic Clinical Skills Development curriculum, whereas the topic *Appliances* did not meet the consensus threshold of 70% (Table 2). For the advanced curriculum, all eight topics were considered necessary (Table 2). The participants suggested additional topics, such as *Ethics of Treatment* and *Interdisciplinary Care*. Unbeknownst to the participants, the proposed topics were included in the draft list of 24 subtopics and their contents that were to be considered in Round Two.

For the predoctoral level, Round Two included subtopics within each of the seven topics. The subtopics within *Appliances* were included to confirm lack of consensus. For the advanced level, seven topics were included in Round Two, except *Supporting Curricula*. *Supporting Curricula* was excluded because CODA Standards for Orthodontic Programs[2] indicated that beginning orthodontists must have understanding of the subtopics within this topic. Twenty-three expert orthodontic educators out of the 48 expert panel nominees participated in Round Two, which was administered between May 4 and June 15, 2020. All 24 subtopics met the consensus threshold of 70% for predoctoral and advanced education Didactic Clinical Skills Development curricula (Table 3), albeit at different revised Bloom's levels of cognition. The subtopics included those within *Appliances*, confirming consensus that all seven topics are necessary for the predoctoral education curriculum. The participants did not suggest additional subtopics. Round Three is the analyses of the Round Two results, as described in the Method Section. Of the 24 subtopics, the revised Bloom's level of cognition mean scores for predoctoral education were at the level of *understand* for 16 and *apply* for eight subtopics (Table 3), while for advanced education, these were at the level of *analyze* for four and *evaluate* for 20 subtopics (Table 3).

## 4 | DISCUSSION

This is the second part in a series of studies to achieve the overarching goal of determining curriculum content in predoctoral and advanced education orthodontics in three levels using the 1993 Guidelines[9] as a model. The aims of the present investigation were to arrive at the expert consensus among orthodontic educators, via a modified Delphi method, on curriculum content for Didactic Clinical Skills Development and to determine the revised Bloom's level of cognition necessary for learner competence in each content area. Participants in a consensus methodology, such as the Delphi method, are more likely to commit to the project and implement the recommendations derived from the results.[13]

### 4.1 | Predoctoral education level

In Round One, the topic *Appliances* did not meet the consensus threshold of ≥70% (Table 2). The Round One questionnaire described *Appliances* as "may include *Principles of appliance design, Types of appliances, and Appliance fabrication*." Two participants who considered *Appliances* unnecessary wrote:

- "Basic understanding of different types of orthodontic appliances is required, but I don't think appliance fabrication is necessary."
- "A rudimentary knowledge of the different types of appliances and how they are fabricated is appropriate but a mastery of that knowledge is unnecessary for a GP (general practitioner)."

These comments indicated that the participants somewhat agreed that *Appliances* was necessary. To confirm consensus, the focus group included the subtopics within *Appliances* in the Round Two questionnaire. Round Two results showed that the subtopics *Principles and application of appliance design* and *Orthodontic materials and appliance fabrication* were rated at the level *understand* (mean ratings of 2.65 and 2.70, respectively) (Table 3), according to revised Bloom's level of cognition. This suggested consensus among participants that *Appliances* is necessary to the predoctoral curriculum.

*Patient history taking and clinical examination*, *Models*, *Radiographic imaging*, and *Extraoral and intraoral photography* are subtopics within the topic *Production of Appropriate Diagnostic Records*. These subtopics received four out of the five highest mean ratings (3.22–3.61) at the level of *apply* (Table 3). A possible explanation for the relatively high ratings is these subtopics' applicability to both orthodontics and general dentistry.

The subtopic *Classification of malocclusion*, described as "may include Angle, Sicher, Scott, and others," received the third-highest mean rating (3.48) at the level of *apply* (Table 3). Perhaps, it is because Angle's classification is a common language used by dentists and orthodontists to communicate a patient's malocclusion.

The subtopics within the topic *Management of Malocclusion* were described as "management includes no treatment, in-person or remote monitoring, interception, treatment, and referral." The subtopic *Complex cases requiring interdisciplinary care* received the lowest mean rating (2.19) among the 24 subtopics at the level of *understand* (Table 3). Another observation regarding subtopics within *Management of Malocclusion* is the inverse relationship of case complexity and participant rating, that is, as case complexity increases, the revised Bloom's level of cognition for predoctoral student competence decreases (Table 3). One participant stated:

- "Orthodontic care for moderate or complex case needs additional advanced training."

The subtopics within the topic *Tooth Movement* received the lowest mean ratings (2.30–2.39) at the level of *understand* (Table 3). One participant commented:

- "They (the general dentists) can have basic knowledge of biology of tooth movement. However, all the applications should be done by orthodontists."

The above comment indicated that orthodontic treatment should be rendered only by orthodontists. However, a recent study showed that "71.6% of general dentists provided some orthodontic services."[15] A participant in our study wrote:

- "Since general dentists are using clear aligners in their practices, let's give them the tools that they should be using to treat patients to the best of their ability… ."

A future study, which is the third part of this series on identifying orthodontic curriculum content, aims to arrive at a consensus among expert orthodontic educators on the essential clinical experience for beginning dentists to be deemed competent in orthodontics.

### 4.2 | Advanced education level

For the advanced education level, the topic *Supporting Curricula* was excluded in Round Two because CODA Standards for Orthodontic Programs[2] indicate that beginning orthodontists must have understanding of

the subtopics within this topic, which include *Biostatistics*, *Pediatrics*, and *The variety of recognized techniques used in contemporary orthodontic practice*. Within each of the sesubtopics are broad categories that if included in Round Two could have caused participant fatigue. Expert consensus for level of cognition for contents of *Supporting Curricula* necessitate a separate Delphi study.

The subtopics *Biomechanics* and *Principles and application of appliance design* had the highest mean rating (5.35) at the level of *evaluate*. The subtopics within the topic *Relationship of morphology to malocclusion* received the next highest mean rating (5.26) at the level of *evaluate* (Table 3). These findings are not surprising since successful treatment depends on thorough diagnosis, treatment planning, and knowledge of treatment tools.

*Videography* received the lowest mean rating (4.33) at the level of *analyze* (Table 3). Two participants commented:

- "It is not something that is routinely utilized in specialty orthodontic practices… ."
- "Videography does not add significant data as compared to the other records."

The subtopic *Epidemiology of malocclusion* received the next lowest rating at the level of *analyze* (4.83) (Table 3). This relatively low rating is possibly due to the subtopic's low applicability in direct patient care. The subtopic *Biology of tooth movement* received the third lowest mean rating (4.87) at the level of *analyze* (Table 3), probably because the knowledge of the molecular mechanisms of tooth movement is difficult to apply chairside. However, understanding these mechanisms is essential in the critical evaluation of literature and techniques that claim to accelerate tooth movement.

The Erasmus Guidelines used verbs to denote competency. For example, in the subtopic *Fixed labial and lingual appliances*, the verbs *describe*, *identify*, and *use* were utilized,[14] which are at *remember* and *apply* levels of revised Bloom's taxonomy. The Erasmus Guidelines did not indicate whether or not the verbs used were in accordance with the revised Bloom's taxonomy. *Principles and application of appliance design*, a similar subtopic in our study, was rated at the level of *evaluate* (Table 3). *Evaluate* was described in the Round Two questionnaire with the verbs *appraise, argue, defend, judge, select, support, value, critique*, and *weigh*, conforming to the revised Bloom's taxonomy. Additionally, in our study, expert panel consensus on level of cognition for advanced education was gathered alongside predoctoral education, possibly introducing bias in the participants' ratings. These matters preclude a direct comparison of our results and the Erasmus Guidelines.

### 4.3 | Comparison of results for predoctoral and advanced education curricula

The mean cognition level for each subtopic was higher for advanced than for predoctoral education curricula (Table 3). Although the highest mean level of cognition for predoctoral education was *apply*, the lowest for advanced education was *analyze* (Table 3). For predoctoral content the mean rating was mostly at the level of *understand* (Table 3), suggesting that, at a minimum, predoctoral Didactic Clinical Skills Development must be learned at the *understand* level. For advanced content, the mean rating was at the *evaluate* level, suggesting that the subtopics must be learned at this level, except for *Videography*, *Diagnostic-set-up*, *Epidemiology of malocclusion*, and *Biology of tooth movement*, which may be learned at the *analyze* level (Table 3). Results of the expert consensus confirmed the higher level of mastery expected in advanced education, which is essential for diagnosis and management of orthodontic cases of varying difficulties.

Mean values across each subtopic within the same level did not show significant differences based on participants' age, years of teaching experience, number of hours in clinical practice, and teaching responsibilities in predoctoral and advanced education programs (data not shown), suggesting the absence of bias based on these demographic data. However, our study is limited because the perspectives of general dentists and other specialists were not included. It is also important to consider the opinion of full-time orthodontic practitioners whose close work with general dentists and other specialists enables them to recognize basic concepts necessary for successful interdisciplinary and comprehensive patient care.

Regarding the future of orthodontic education in the next decade, several participants commented on the role of technology and digital applications in personalized therapy, treatment modality, virtual treatment planning and progress tracking. In terms of student learning, participants projected that remote and online learning will be commonplace. One participant predicted that more information on clinical evaluation and diagnosis will be given to predoctoral students to "*help them in practice in either treating or properly referring patients*". Another participant wrote:

- "Orthodontists must be prepared to handle more challenging interdisciplinary cases with complex mechanics as GPs will take on more simpler, non-complex orthodontic cases with the advancements in aligner mechanics, intraoral scanning and in-office 3D printing."

Our study generated a consensus among expert orthodontic educators on predoctoral and advanced orthodontic education curriculum content and a panorama of educational objectives that could be used as a template for curriculum design in Didactic Clinical Skills Development. Due to differences in the number of curriculum hours among programs,[7,8] adjustment of didactic methods and/or curriculum hours may be necessary to achieve the learning objectives. The didactic classroom learning should provide the fundamental concepts as learners transition in clinical care and for further training after graduation. The curriculum content for essential clinical experience is a topic for a future study.

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