

Review Article

Learning Styles in undergraduate dentistry students: A systematic review

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ABSTRACT

Objective: To evaluate the prevalence of Learning Styles (LS) among undergraduate dentistry students (UDS), **Method:** Cochrane manual's methodology and PRISMA statement were used. Four databases were searched, and the studies were selected based on eligibility criteria. The search strategy was *Learning Style AND Dentistry* and *Learning Style AND dental student*.

Results: A total of 30 articles were included, 17 of which used the Visual, Aural, Read-write and Kinesthetic (VARK) questionnaire, 8 the Kolb LS Inventory (LSI), 3 the Honey-Alonso questionnaire (CHAEA) and 3 the Felder and Solomon LS index (ILS). The studies that allowed us to extract all the necessary data to calculate the global percentages for each instrument were grouped together. For VARK, LSI, CHAEA and ILS the highest number and percentage of learning styles were 1089 (50.4 %) multimodal, 518 (32.7 %) divergent, 239 (46.7 %) reflectors and 107 (64.8 %) active, 130 (78.8 %) sensitive, 138 (83.6 %) visual and 106 (64.3 %) sequential, respectively.

Conclusions: There is a tendency for multimodal, divergent and reflective LS to increase among clinical students, unlike initial and preclinical dentistry students, who lean towards unimodal, convergent and theoretical LS. This dynamism in LS could be influenced by the different methodologies strategies used in the preclinical and clinical courses.

1. Introduction

The contemporary higher education is based on constructivism, in which students build their knowledge by incorporating new and previous concepts from the student's cognitive structure as an anchor for the new information [1]. Thus, students become the center of the teaching-learning process that takes place in universities, as reflected in recent curricular changes in university careers, moving from a teacher-centered approach (traditional curriculum) to a curriculum focused on the student [2]. This is not a simple pursuit since there are multiple factors that can influence university students academic performance [3].

As a result, one important aspect to examine from the constructivist perspective is an understanding of the Learning Styles (LS) that students from specific locations, careers, or institutions, may exhibit [4]. A LS has been defined as the way individuals learn, it relates to the conditions under which individuals concentrate, absorbs, process and retain new

information and skills, namely how individuals integrate with learning conditions (including cognitive, affective, physical, and environmental aspects) that can facilitate the learning process [4,5]. Recognizing LS is important for faculty members because it helps them to develop more than one learning approach to encourage more-in depth learning [7], to maximize the student learning potential in an inclusive way, that considers the diversity found in the classroom [5,6]. Also, the students' knowledge from their own learning preferences, empowers them to apply various techniques to enhance learning and increases their academic satisfaction [6].

It has been suggested that the academic must be able to assess student LS regularly and adjust curriculum to optimize learning [5,6]. But evidence has shown little support to this assumption, furthermore, the idea is not to adapt the teaching to the presumed innate LS, but to enhance the learning experience encouraging the use of diverse approaches [7]. On the other hand, various LS theories have been proposed, as having the instruments to evaluate them, and according to a

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recent review [5], the most frequently used instruments are the Visual, Aural, Read-write and Kinesthetic (VARK) questionnaire, Kolb's Learning Style inventory (LSI), Honey-Alonso questionnaire (CHAEA), and the Index of Learning Style (ILS). Each one of these instruments have evidence of validity and reliability [5].

The VARK questionnaire, is a self-reported instrument that indicates a preference of the person for a particular style or combination of styles. It's based in Neil Fleming model of neurolinguistic programming, assuming that information is received by sensory means, and each person have sensory preferences. The sensory preferences are visual (retaining information in tables, graphs, and other devices rather than words), auditory (learning through oral lessons and conversation), read-write (learn from printed text) and kinesthetic (learn from direct practice). The sensory preferences could be *unimodal* or *multimodal*, when involves more than one sensory preference, being *bimodal*, *trimodal* or *quadmodal*, when they prefer, two, three and four sensory preferences, respectively [5].

The LSI is an instrument based in Kolb's Theory of experiential learning, according to which, learning occurs in a cyclical process of four steps: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This can be combined at different times of learning to form a predominant LS, which can be *accommodator*, *diverger*, *assimilator* or *converger*. The *accommodator* prefers concrete experience and active experimentation, resulting in a student who learns by doing things like carrying out plans and experiments, the *diverger* prefers concrete experience and reflective observation, resulting in a student who learns by considering multiple perspectives from a previous experience, the *converger* prefers the abstract conceptualization and active experimentation, resulting in a student who learns through the practical application of ideas, and the *assimilator* prefers abstract conceptualization and reflective observation, resulting in students who learn through the synthesis of information and by creating unifying theories or patterns [5].

The CHAEA is an instrument based in Kolb's Theory of experiential learning and the Honey-Alonso model and propose that students can be classified as activist, reflector, theorist and pragmatist, equivalent to the LS accommodator, diverger, assimilator and converger respectively. *Activist* people tend to get directly involved in activities, preferring short activities with immediate results. *Pragmatists* have a predisposition to test new theories, ideas, and techniques, with a tendency to make decisions and solve problems. *Reflectors* tend to analyze experiences from different perspectives, focusing on data collection and their analysis. *Theorists* are methodical students who seek to establish conclusions through the logical order of sequences, events, and facts, which predominates in their logical and rational thinking [5].

Finally, the ILS is an instrument based in Felder-Silverman model, that distinguishes four LS dimensions. The student can be classified as *sensitive* or *intuitive*, *visual* or *verbal*, *active* or *reflective* and *sequential* or *global*. *Sensitive* students learn through the perception of information through the senses, preferring specific facts and data meanwhile *intuitive* students learn using memory and are good at formulating theories over learning details. *Visuals* students prefer the presentation of information through observation such as graphs, videos, diagrams, and demonstrations, as opposed to the *verbal* students who prefer words either in aural or written form. *Active* students learn best by doing practical activities and interacting as a group, as opposed to *reflective* students, who learn best by reflecting on information and prefer to work alone. *Sequential* students understand the information in a partial way and later in a sequential way they order all the information; they are skilled in understanding or creating sequences, in contrast to *global* students, quickly understand the global idea of what is studied but not in an orderly or sequential way [5].

As in most biomedical sciences, dentistry students must comply with a clinical component, which leads to providing patient care, in addition to their academic responsibilities. Therefore, dental students are exposed to different teaching strategies during preclinical and clinical

subjects. Subsequently, considering dental students' LS is important to visualize how the curricula affect the learning of dentistry students, according to a contemporary educational constructivist perspective [4–6]. As a result, the aim of this systematic review was to evaluate the current literature on the prevalence of LS among undergraduate dentistry students (UDS).

2. Materials and method

The methodology of the Cochrane Manual of Systematic Reviews of interventions [8] and the PRISMA statement for reports of systematic reviews [9] were used to answer the question what is the prevalence of LS among UDS? According to the population, intervention, comparison, and outcome (PICO) criteria, the UDS are considered the studied population, the intervention correspond to the application of an instrument that determines their LS, comparison does not apply in this case and finally we consider as outcome the prevalence of the different LS. The search strategy used was *Learning Style AND Dentistry* and *Learning Style AND dental student* in the following databases: Pubmed, ScienceDirect, Scopus and SciELO. The search was conducted from the starting coverage date to January 30, 2025.

The inclusion criteria consisted of cross-sectional studies that evaluated the prevalence of LS among UDS. LS could be assessed through different types of instruments. The exclusion criteria consisted in validation studies of LS surveys, systematic or narrative reviews, book chapters, and full text not available. Two independent reviewers (FV N and HB V) searched the databases, remove duplicates, and blindly assessed titles and abstracts from identified studies according to eligibility criteria. They also searched the bibliographic references. Articles that were considered eligible for inclusion were full text read by the same reviewers to ensure compliance with the selection criteria. A third team member (GU C) intervened to resolve the different criteria between the two reviewers.

The following data were extracted: author, year of study, population, country, demographic characteristics, student's academic level, type of instrument used to measure the LS, prevalence of different types of LS and principal findings. The individual quality of the selected studies was assessed using the National Health and Medical Research Council (NHMRC) designation of levels of evidence [10].

3. Results

3.1. Search and selection of included articles

Fig. 1 shows a search summary and selection process towards the articles in this review. Using the search strategy, a total of 5971 articles were found in the various databases (PubMed 311, ScienceDirect 5332, Scopus 321 and SciELO 7). After removing duplicate articles from the databases, the total articles were reduced to 4775. After a review of the title and abstract, 56 articles were selected, and through a search of bibliographic references, 2 more articles were added. As a result, a total of 58 were subjected to a thorough reading to determine whether they met the selection criteria. 28 articles were excluded [11–39], leaving a total of 30 articles included in the current review [40–69]. The reasons for exclusion are shown in Table 1.

3.2. Analysis of the level of evidence

All the articles included in this systematic review were classified in the evidence level III-3, according to the National Health and Medical Research Council (NHMRC) designation of evidence levels [10].

3.3. Study characteristics

From the 30 included articles, 17 articles applied the VARK questionnaire [40–56], eight used the LSI [56–63], three the CHAEA [64–66]

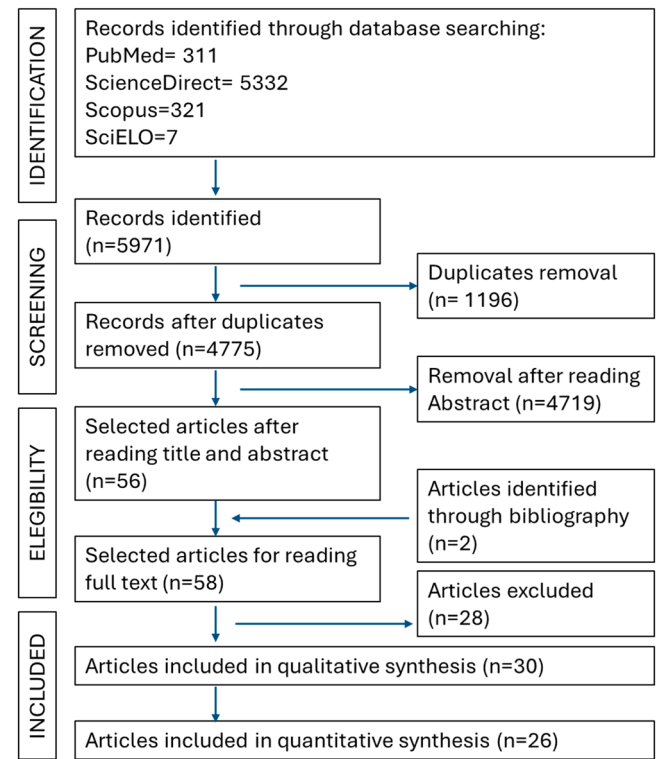


Fig. 1. Flow diagram of the study.

and three articles the ILS [67–69]. It is important noticing that one article [56], assessed both VARK questionnaire and the Kolb’s LS inventory. The included studies accounted for a total of 5264 subjects (2813 studied with VARK questionnaire, 1583 LSI, 538 with CHAEA and 330 with ILS. Regarding the country where the studies were carried out articles using VARK questionnaire were from India, Pakistan, Saudi Arabia, Iran, Malaysia, and Poland, eight of the studies using LSI, four were developed in Iran, two in Chile, one in China and one in Saudi Arabia. The three studies that used CHAEA, were conducted in Peru, Chile and Cuba. The studies that used the ILS index were developed in Poland, Brasil and Iran. The details of each study such as the number of participants, academic level, percentage of men and women, average age, percentages of each LS and main findings can be seen in Tables 2–5.

3.4. Synthesis of results included studies

The LS prevalence among UDS was variable among individual studies. For analysis purposes, the studies were divided according to the instrument used to evaluate LS, grouping the studies that allowed the extraction of all the data necessary to calculate global percentages for each instrument, obtaining the following results:

3.4.1. Studies using VARK questionnaire

The VARK questionnaire classifies LS as *unimodal* (visual, aural, read/write or kinesthetic) and *multimodal* (bimodal, trimodal or quadmodal, mixing more than one unimodal LS), of the 17 studies that applied this questionnaire, 13 could be grouped to perform a pooled analysis [40,41, 43,44,46–51,53–55], covering 2164 participants, of which 1075 (49.6 %) preferred the unimodal style, while 1089 (50.4 %) preferred the multimodal style. However, the most preferred unimodal style was Kinesthetic with 355 (16.4 %) and the most preferred multimodal style was Bimodal with 419 (19.4 %). The details can be seen in Table 6.

3.4.2. Studies using LSI

Kolb’s LS inventory classifies the LS as *accommodator*, *diverger*,

Table 1
Articles excluded after full text reading.

Autor	Year	Reason for exclusion
Berlocher et al. [11]	1985	Full text not available
Morris [12]	2000	Analyze personality styles and not learning styles
Lindemann et al. [13]	2001	Analyze study strategies and not learning styles
Acuña et al. [14]	2009	Does not allow to extract prevalence data of learning styles
Choi et al. [15]	2009	Compares learning styles in relation to activity performed
Alcota et al. [16]	2011	Intentionally apply the survey to a specific group of students
Shenoy et al. [17]	2013	Data do not coincide within the same study.
Sarabi-Asiabar et al. [18]	2014	Does not allow to extract prevalence data of learning styles
Wilkinson et al. [19]	2014	Does not distinguish between medical and dentistry students
Narayana et al. [20]	2014	Data do not coincide within the same study.
Farkas et al. [21]	2016	Does not allow to extract prevalence data of learning styles
Martinez-Sandoval et al. [22]	2016	Does not allow to extract prevalence data of learning styles
Omar [23]	2017	Does not allow to extract prevalence data of learning styles
Siddiquei et al. [24]	2018	Does not allow to extract prevalence data of learning styles
Butt et al. [25]	2018	Does not allow to extract prevalence data of learning styles
AlQahtani et al. [26]	2018	Data are the same as in the study of Aldosari et al. 2018
Khanal et al. [27]	2019	Does not allow to extract prevalence data of learning styles
Marwaha et al. [28]	2019	A longitudinal study and does not allow to extract data from undergraduate dentistry students
Mozaffari et al. [29]	2020	Does not allow to extract prevalence data of learning styles
Chaudhry [30]	2020	Does not allow to extract prevalence data of learning styles
Salter et al. [31]	2020	Intentionally apply the survey to a specific group of students
Tsatalis et al. [32]	2021	Classifies students according to the stage of the learning cycle.
Ardila et al. [33]	2021	Does not allow to extract prevalence data of learning styles
Fahim et al. [34]	2021	Does not allow to extract prevalence data of learning styles
Pendyala et al. [35]	2021	Does not allow to extract prevalence data of learning styles
Hashem et al. [36]	2022	Data do not coincide within the same study.
Ganji et al. [37]	2022	Does not allow to extract prevalence data of learning styles
Tonkaboni et al. [38]	2022	Does not allow to extract prevalence data of learning styles
B Oliveira et al. [39]	2023	Does not allow to extract prevalence data of learning styles

assimilator, and *converger*. The eight studies that applied this test could be grouped for pooled analysis [56–63], covering 1583 participants, of which 325 (20.5 %) were convergent, 518 (32.7 %) were divergent, 337 (21.3 %) were assimilators and 403 (25.5 %) were accommodators. Details can be seen in Table 7.

3.4.3. Studies using CHAEA

The Honey-Alonso questionnaire classify the LS as *activist*, *reflector*, *theorist*, and *pragmatist*. The three studies that applied this test could be grouped together for pooled analysis [65,66], involving 512 participants, of which 76 (20.5 %) were activist, 239 (46.7 %) were reflector, 114 (22.3 %) were theorist and 83 (16.2 %) were pragmatist. Details can be seen in Table 8.

3.4.4. Studies using the ILS

This instrument classifies the LS in four non-mutually exclusive dimensions: *active-reflective*, *sensitive-intuitive*, *visual-verbal* and *sequential*.

Table 2

Studies that report LS among UDS, measured using the VARK questionnaire.

Author	Year	n	Academic level	Demographic characteristics	Population	Unimodal Learning Style	Multimodal Learning Style	Principal Findings
Kaczmarek et al. [40]	2010	78	5th	NR	Poland	Unimodal (46.2 %) 2.6 % Visual 24.3 % Aural 1.3 % Read/write 18 % Kinesthetic	Multimodal (53.8 %) 14.1 % Bimodal 21.8 % Trimodal 17.9 % Quadmodal	Greater preference for multimodal learning, however, there was no statistically significant difference between unimodal and multimodal
Kumar et al. [41]	2011	110	NR	NR	India	Unimodal (72 %) 13 % Visual 17 % Aural 20 % Read/write 22 % Kinesthetic	Multimodal (28 %) 22 % Bimodal 5 % Trimodal 1 % Quadmodal	Greater unimodal preference, but study conducts general analysis among medical, dental and pharmaceutical students
Haq [42]	2012	153	1st to 3rd	NR	Pakistan	Unimodal (69.3 %) 11.7 % Visual 19 % Aural 17 % Read/write 21.6 % Kinesthetic	Multimodal (30.7 %) NR% Bimodal NR% Trimodal NR% Quadmodal	Greater predominance of the unimodal Kinesthetic style, however, was not statistically significant.
Prabha [43]	2013	66	1st	NR	India	Unimodal (58 %) 17.3 % Visual 22.7 % Aural 0 % Read/write 18 % Kinesthetic	Multimodal (42 %) 37.1 % Bimodal 4.9 % Trimodal 0 % Quadmodal	Greater preference for multimodal, bimodal type. However, no statistical significance analyses were performed.
Al-Saud et al. [44]	2013	105	1st	60.9 % men, 39.1 % women, average age 18 years old.	Saudi Arabia	Unimodal (41 %) 2.9 % Visual 20 % Aural 2.9 % Read/write 15.2 % Kinesthetic	Multimodal (59 %) 21 % Bimodal 19 % Trimodal 19 % Quadmodal	Students with a Quadmodal preference statistically had higher GPA than those with a unimodal preference.
Saran et al. [45]	2015	60	1st to 2nd	NR	India	Unimodal (46.7 %) NR% Visual NR% Aural NR% Read/write NR% Kinesthetic	Multimodal (53.3 %) 20 % Bimodal 5 % Trimodal 28.3 % Quadmodal	Nearly 50 % of 1st year students were quadmodal whereas 55 % of 2nd year students were unimodal in which kinesthetic preference was dominant. Mean V and A scores were significantly higher for 1st year than 2nd year students.
Bennadi et al. [46]	2015	120	1st to 4th	60 % women 40 % men average age NR	India	Unimodal (24.1 %) 5.8 % Visual 4.2 % Aural 6.6 % Read/write 7.5 % Kinesthetic	Multimodal (75.9 %) 30 % Bimodal 36.7 % Trimodal 9.2 % Quadmodal	Most clinical students, 43 out of 50 (86 %) prefer a multimodal learning style.
Marwaha et al. [47]	2015	163	1st to 2nd	80.9 % women 19.1 % men Average age NR	India	Unimodal (51.0 %) 3.0 % Visual 15.0 % Aural 6.0 % Read/write 27.0 % Kinesthetic	Multimodal (49.0 %) 23.0 % Bimodal 17.0 % Trimodal 9.0 % Quadmodal	The preference for the Visual type of unimodal style was statistically higher in first year than in second year, as well as for women compared to men.
Iqbal et al. [48]	2015	160	1st to 4th	NR	Pakistan	Unimodal (51.0 %) 15.4 % Visual 20.6 % Aural 2.5 % Read/write 12.5 % Kinesthetic	Multimodal (49.0 %) 2.0 % Bimodal 0.0 % Trimodal 47.0 % Quadmodal	Unimodal and bimodal preference from first to fourth year was well balanced. Multimodal preference was balanced in first, third and fourth year but lower in second year.

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Table 2 (continued)

Author	Year	n	Academic level	Demographic characteristics	Population	Unimodal Learning Style	Multimodal Learning Style	Principal Findings
Asiry [49]	2016	269	1st to 5th	100 % men average age NR	Saudi Arabia	Unimodal (41.6 %) 7.4 % Visual 0.0 % Aural 5.2 % Read/write 14.5 % Kinesthetic	Multimodal (58.4 %) 18.2 % Bimodal 18.2 % Trimodal 22 % Quadmodal	Unimodal and multimodal preferences remained unchanged over the five years. In addition, students showed strong unimodal preferences for Kinesthetic.
Nasiri et al. [50]	2016	88	4th to 6th	63.6 % women 36.4 % men average age NR	Iran	Unimodal (1.3 %) 0 % Visual 1.3 % Aural 0 % Read/write 0 % Kinesthetic	Multimodal (98.7 %) 18.1 % Bimodal 56.8 % Trimodal 23.8 % Quadmodal	Of the 88 participants who responded to the questionnaire, 87 preferred multimodal learning styles.
Wong et al. [51]	2017	49	1st	NR	Malaysia	Unimodal (89.8 %) 12.2 % Visual 22.5 % Aural 34.7 % Read/write 20.4 % Kinesthetic	Multimodal (10.2 %) 6.1 % Bimodal 4.1 % Trimodal 0 % Quadmodal	Analysis was carried out comparing medical, dental and pharmaceutical students
Singh et al. [52]	2017	185	3rd to 4th	57 % women 37 % men average age NR	India	Unimodal (25.7 %) NR% Visual NR% Aural NR% Read/write NR% Kinesthetic	Multimodal (74.3 %) 16.3 % Bimodal 10 % Trimodal 48 % Quadmodal	Greater preference for Quadmodal multimodal style, followed by kinesthetic unimodal learning style.
Akhlaghi et al. [53]	2018	200	2nd to 6th	56.5 % women 43.5 % men average age NR	Iran	Unimodal (48.5 %) 1 % Visual 24 % Aural 8 % Read/write 15.5 % Kinesthetic	Multimodal (51.5 %) 22.5 % Bimodal 13.5 % Trimodal 15.5 % Quadmodal	There was a significant association between GPA and the reading/writing learning style preference
Aldosari et al. [54]	2018	368	1st to 5th	26.9 % women 73.1 % men average age NR	Saudi Arabia	Unimodal (37.0 %) 7.1 % Visual 12.5 % Aural 5.2 % Read/write 12.2 % Kinesthetic	Multimodal (63.0 %) 20.9 % Bimodal 18.5 % Trimodal 23.6 % Quadmodal	Women had a higher probability of preferring a bimodal style compared to men.
Nazir et al. [55]	2018	389	2nd to 6th	53.5 % women 46.5 % men Average age 20.42 ± 0.99 NR	Saudi Arabia	Unimodal (76.0 %) 18.8 % Visual 18.5 % Aural 14.7 % Read/write 23.7 % Kinesthetic	Multimodal (24.0 %) 19.0 % Bimodal 4.0 % Trimodal 1.0 % Quadmodal	Clinical students, statistically, have a preference for the Visual type unimodal style. The students with high GPA preferred multimodal learning style (25.4 %) whereas most of the students with low GPA (32.9 %) learned through doing things (kinesthetic).
Taheri et al. [56]	2021	250	2nd to 6th	48.4 % women 51.6 % men average age 24 ± 2.9	Iran	Unimodal (80.4 %) 11.6 % Visual 24.8 % Aural 31.6 % Read/write 12.4 % Kinesthetic	Multimodal (19.6 %) 5.6 % Bimodal 14 % Trimodal or Quadmodal	No significant relationship was found between the learning styles (Kolb and VARK) and creativity with academic achievement.

NR: not reported.

GPA: Grade Point Average.

global. In addition, each dimension can present an intermediate preference called balanced. Two of the three studies that applied this test could be grouped for pooled analysis [67–69], involving 512 participants, of whom had preferences for the following styles in the respective domains; 107 (64.8 %) were active, 130 (78.8 %) were sensitive, 138

(83.6 %) were visual and 106 (64.3 %) were sequential. Details can be seen in Table 9.

Table 3

Studies that report LS among UDS, measured using LSI.

Author	Year	n	Academic level	Demographic characteristics	Population	Resulted Learning Styles	Principal Findings
Concha et al. [57]	2009	62	3rd	64.5 % women 35.5 % men average age NR	Chile	51 % Converger 15 % Diverger 18 % Assimilator 16 % Accommodator	Convergent and divergent students obtained better grades in the practical area than in the cognitive area. Most of the poor grades recorded in the cognitive area correspond to divergent students.
AlQahtani et al. [58]	2014	291	1st to 6th	42.3 % women 57.7 % men average age NR	Saudi Arabia	19.6 % Converger 33 % Diverger 22.7 % Assimilator 24.7 % Accommodator	The students preferred the Assimilating style during their early preclinical years, they preferred the Diverging style during their later clinical years.
Hosseini [59]	2015	162	1st	47.5 % women 52.5 % men average age 24.3 ± 5.5	Iran	24.1 % Converger 14.2 % Diverger 53.1 % Assimilator 8.6 % Accommodator	Although students with Assimilating and Converging learning styles performed better in their educational achievement, it was not statistically significant.
Fuentes-Nawrath et al. [60]	2018	372	1st to 6th	56 % women 44 % men average age NR	Chile	3 % Converger 63 % Diverger 8 % Assimilator 26 % Accommodator	The learning style in the fourth, fifth and sixth grades was predominantly divergent, ending with an accommodating style in sixth grade students. It can be concluded that psychological types and learning styles were not homogeneous in the different curricular levels.
Wang et al. [61]	2019	121	2nd	41.3 % women 58.7 % men average age 19.1 ± NR	China	55.4 % Converger 7.4 % Diverger 23.1 % Assimilator 14.1 % Accommodator	Learning style did not influence participants' satisfaction and did not predict their satisfaction with the traditional and inverted classroom model approaches.
Taheri et al. [56]	2021	250	2nd to 6th	48.4 % women 51.6 % men average age 24 ± 2.9	Iran	5.2 % Converger 14.8 % Diverger 16 % Assimilator 64 % Accommodator	No significant relationship was found between the learning styles (Kolb and VARK) and creativity with academic achievement.
Armandeh A et al. [62]	2021	205	1st	58.5 % women 41.5 % men average age 23.3 ± 3.4	Iran	32.7 % Converger 26.3 % Diverger 31.7 % Assimilator 9.3 % Accommodator	A significant correlation was reported between learning style and academic achievement, in a way that converges achieved higher GPAs, compared to divergers.
Hamzenejad et al. [63]	2022	120	1st to 3rd	65.0 % women 35.0 % men average age 21.5 ± 2.8	Iran	32.5 % Converger 46.7 % Diverger 9.2 % Assimilator 11.6 % Accommodator	Divergent learning styles substantially increased students' satisfaction with e learning compared to other learning styles.

NR: not reported.

GPA: Grade Point Average.

4. Discussion

The aim of this systematic review was to examine the current literature, evaluating the LS prevalence among UDS. In this review, the LS were assessed through different types of questionnaires. The instruments used in the included studies were the VARK questionnaire, Kolb's LS inventory (LSI), Honey-Alonso questionnaire (CHAEA) and the Felder and Solomon LS index (ILS).

The comparison between the different LS proposed by the different questionnaires is complex. The VARK LS are oriented to the sensory preference by which students receive the information, independent of its processing, on the other hand both LSI and CHAEA, are framed in Kolb's Theory of experiential learning, focusing on the student's preferred moment in the learning cycle. Finally, the learning model proposed by Felder and Solomon, contemplates learning in four dimensions; processing, perceiving, receiving and understanding information [5]. This means that the results obtained using different measurement instruments cannot be compared.

This review reveals that the most used instrument to report LS among UDS is the VARK questionnaire, which has been reported in other undergraduate healthcare students [5]. According to the studies that applied this questionnaire, the UDS present both *multimodal* and

unimodal LS. However, a more thorough examination on the studies, reveals that the *unimodal* LS seems to present more frequently in students from initial courses, while studies focused their sampling on students from late stages of the career, show a trend towards a higher frequency of *multimodal* styles [40,42,43,47,48,52–54]. This is evident in the study by Bennadi et al. [46], who discovered statistically significant differences between preclinical and clinical students, with the latter preferring *multimodal* LS. Also, in Nasiri et al. study [50], they observed that only one clinical student had preference towards the *unimodal* style, meanwhile the rest of them being *multimodal*. Wong et al. [51] in a study conducted on first-year dentistry students, discovered that 89.9 % had a preference towards *unimodal* learning. However, students prefer *unimodal* LS in beginning courses and *multimodal* LS in advanced courses should be carefully analyzed, since there are studies that find different results [44,45,49,55]. Therefore, as UDS progress through the academic years, it appears that they begin to interact with teaching methodology, such as laboratory classes and tutorials, among others, that encourage them to develop *multimodal* LS, a situation that has already been described in nursing students [70].

Kolb's questionnaire is based on David Kolb's experiential learning theory, where the student learns through a cycle process of concrete experience, reflective observation, abstract conceptualization, and

Table 4

Studies that report LS among UDS, measured using CHAEA.

Author	Year	n	Academic level	Demographic characteristics	Population	Resulted learning styles	Principal Findings
Ortiz-Fernández et al. [64]	2014	26	1st	42 % women 58 % men average age 18.8 years ± 2.3	Peru	Beginning of the year 11.5 % Activist 26.9 % Reflector 42.3 % Theorist 19.3 % Pragmatist Ending of the year 0 % Activist 19 % Reflector 81 % Theorist 0 % Pragmatist	There was no relationship between learning styles and academic performance.
Barrios-Penna et al. [65]	2018	490	1st to 5th	51 % women 39 % men average age NR	Chile	1st year 21 % Activist 45 % Reflector 19 % Theorist 15 % Pragmatist 2d year 20 % Activist 45 % Reflector 18 % Theorist 17 % Pragmatist 3rd year 16 % Activist 47 % Reflector 21 % Theorist 16 % Pragmatist 4th year 7 % Activist 41 % Reflector 41 % Reflector 33 % Theorist 19 % Pragmatist 5th year 6 % Activist 56 % Reflector 21 % Theorist 17 % Pragmatist Total 15.3 % Activist 46.3 % Reflector 21.9 % Theorist 16.5 % Pragmatist	The active, reflective and pragmatic style presented a fluctuating development as the academic years progressed; with the exception of the theoretical style, which demonstrated a steady increase.
Betancourt-Gamboa et al. [66]	2021	22	1st	77.3 % women 22.7 % men average age NR	Cuba	4.5 % Activist 54.6 % Reflector 31.8 % Theorist 9.1 % Pragmatist	In the female gender, the reflective style predominates with 45.4 %, followed by the theoretical with 22.7 %. In turn, the male gender shows equal frequency in the theoretical and reflective styles, both with 9 %.

NR: not reported.

active experimentation. Kolb proposes that LS can be determined by identifying the two stages of the learning cycle that the student prefers to incorporate and process information, being *accommodator*, *diverger*, *assimilator* or *converger* [5]. Concha et al. [57] found that 51 % of a group of third-year students had a *convergent* LS. In addition, finding a statistically significant relationship between academic performance and LS, with students with *convergent* and *divergent* LS obtaining better grades in the practical area compared to the cognitive area. Wang et al. [61] found

that 55.4 % of second-year students had *convergent* LS and when comparing the degree of satisfaction between traditional classes and inverted classroom model in relation to LS, the latter was not significant. Armandeh et al. [62] found that 32.7 % of first-year students had a *convergent* LS, this being the highest value in the study and that these students had statistically a better grade point average. On the other hand, AlQahtani et al. [58] found that the largest number of students (33 %) from first to sixth year had *divergent* LS, however, preclinical

Table 5

Studies that report LS in UDS, measured using ILS.

Author	Year	n	Academic level	Demographic characteristics	Population	Resulted learning styles	Principal Findings
Kaczmarek et al. [67]	2009	80	5th	NR	Poland	77.5/22.5 % Act/Refl 86.3/13.7 % Sen/Int 82.5/17.5 % Vis/Verb 65.0/35.0 % Seq/Glo	The results indicated that students preferred active, sensing, visual and sequential learning styles. The highest grades had students who were classified as active and sequential learners. The lowest grades had those who were classified as verbal, reflective intuitive and global learners. The highest rate of exams repetition was shown in students that preferred active, verbal and sensing learning styles, the lowest rate was shown in students who preferred reflective and intuitive style.
Dalmoin et al. [68]	2018	165	3rd	74.0 % women 26.0 % men average age 21 ± 2	Brasil	22 %/60 %/18 % Act/Balanc/Refl 64 %/35.4 %/0.6 % Sen/Balanc/Int 42 %/44 %/14 % Vis/Balanc/Verb 23 %/68 %/9 % Seq/Balanc/Glo	No relationship was found between learning styles, age and gender
Baherimoghadam [69]	2021	85	5th to 6th	58.8 % women 41.2 % men average age + -NR	Iran	52.9/47.1 % Act/Refe 71.7/28.3 % Sen/Int 84.7/15.3 % Vis/Verb 63.5/36.5 % Seq/Glo	The correlation between satisfaction and the dimensions of learning style showed that the active dimension of processing information had a significant relationship with the level of satisfaction. In the understanding dimension, a relatively strong correlation was observed in the Global dimension.

NR: not reported.

Table 6

Summary of studies reporting LS in USD, using the VARK questionnaire.

Author	Unimodal				Multimodal			Total
	Visual	Aural	Read/Write	Kinesthetic	Bimodal	Trimodal	Quadmodal	
Kaczmarek et al. [40]	2	19	1	14	11	17	14	78
Kumar et al. [41]	14	19	22	24	24	6	1	110
Prabha et al. [43]	11	15	0	12	24	4	0	66
Al-Saud et al. [44]	3	21	3	16	22	20	20	105
Bennadi et al. [46]	7	5	8	9	36	44	11	120
Marwaha et al. [47]	4	25	10	44	35	28	17	163
Iqbal et al. [48]	25	33	3	20	4	0	75	160
Asiry [49]	20	39	14	39	49	49	59	269
Nasiri et al. [50]	0	1	0	0	16	50	21	88
Wong et al. [51]	6	11	17	10	3	2	0	49
Akhlaghi et al. [53]	2	48	16	31	45	27	31	200
Aldosari et al. [54]	26	46	20	44	77	67	87	367
Nazir et al. [55]	73	72	59	92	73	16	4	389
	193	354	173	355	419	330	340	2164
%	8,9	16,4	7,9	16,4	19,4	15,3	15,7	100
%	49,6				50,4			

students (first to second year) preferred the *assimilating* style, while clinical students (third to sixth year) leaned towards the *divergent* style, being statistically significant. Hamzenejad et al. [63] found 46.7 % of *divergent* students, who statistically showed a high degree of satisfaction with e-learning, in the same line of previous studies, Fuentes-Nawrath et al. [60] found that 63 % of fourth, fifth and sixth year students were *divergent*. Taheri et al. [40] reported in a sample of second to sixth year students, that 64 % of them had an *accommodating* LS. Finally, Hosseini et al. [59] found 53.1 % of students with *assimilating* LS, a situation expected from the point of view that they are first-year students who have mainly theoretical subjects in basic sciences and not preclinical or clinical subjects. Regarding the diversity of LS in the studies, it could be explained because students from first to third year have a fundamentally theoretical and preclinical training, which could favor learning using abstract conceptualization, unlike fourth, fifth and sixth year students, who are doing clinical practices that tend to focus on fulfilling multiple treatments related to various clinical cases, as well as

on the integration of knowledge to determine diagnoses, prognoses and treatment plans, which should favor learning using concrete experience such. However, this situation must be analyzed with caution, since it is documented that students can change their LS during their university life [71].

The CHAEA categorizes students according to their LS as *activist*, *reflector*, *theorist* and *pragmatist* [5]. The study by Ortiz-Fernández et al. [64], found that first-year dentistry students LS changed after the first year studying the career, with *theorist* students increasing and *reflector* students decreasing, and it is highlighted that at the end of the academic year, no student presented *activist* or *pragmatist* LS. Barrios-Penna et al. [65] studied students from the first to fifth academic year and found a consistent frequency of *reflector* LS that exceeds 40 % at all academic levels, with the highest value in the final year of study at 56 %. In addition, a high percentage of the *theorist* LS was observed in this study, which remained between 18 % and 33 %. However, in all courses, the *pragmatist* LS was always less than 20 %, and as the academic years

Table 7

Summary of studies reporting LS in USD, using LSI.

Author	Converger	Diverger	Assimilator	Accommodator	Total
Concha et al. [57]	32	9	11	10	62
ALQahtani et al. [58]	57	96	66	72	291
Hosseini [59]	39	23	86	14	162
Fuentes-Nawrath et al. [60]	11	234	30	97	372
Wang et al. [61]	67	9	28	17	121
Taheri et al. [56]	13	37	40	160	250
Armandeh et al. [62]	67	54	65	19	205
Hamzenezjad et al. [63]	39	56	11	14	120
	325	518	337	403	1583
%	20,5	32,7	21,3	25,5	100

Table 8

Summary of studies reporting LS in USD, using CHAEA.

Author	Activist	Reflector	Theorist	Pragmatist	Total
Barrios-Penna et al. [65]	75	227	107	81	490
Betancourt-Gamboa et al. [66]	1	12	7	2	22
	76	239	114	83	512
%	14,8	46,7	22,3	16,2	100

progressed the prevalence of *activist* LS decreased from 21 % to 6 % in fifth year. Betancourt-Gamboa et al. [66], found 54.6 % of students as *reflectors* and 31.8 % as *theoretical*. However, the study group was only 22 students, of which 17 were women, without finding statistical relationships with the gender variable.

These changes in LS are most likely due to the various scenarios that students face as they progress through their academic years, emphasizing preclinical and clinical activities as the main distinguishing factor when compared to other university careers. Now, the shift toward *reflector* and *theorist* LS is most likely influenced by clinical practice, as they must adopt a tendency to methodically collect clinical and imaging data from patients to logically propose diagnoses and treatment plans, a situation that students in their first years of their careers do not face.

Finally, ILS categorizes LS in four non-mutually exclusive dimensions: *active* or *reflective*, *sensitive* or *intuitive*, *visual* or *verbal* and *sequential* or *global* [5]. The study by Kaczmarek et al. [67], reported a group of UDS of fifth year characterized by being predominantly *active*, *sensitive*, *visual* and *sequential*, results that are consistent with the findings of the studies conducted by McCrow et al. [72], Campos et al. [73], Alharbi et al. [74] on nurses, nutrition and nursing students respectively, in which the studied groups presented the same predominance towards *active*, *sensitive*, *visual* and *sequential* students. On the other hand, Dalmoín [68] et al. found the same sensitive predominance, but it was balanced between active-reflective, visual-verbal and sequential-global, all of them presenting low inclination towards

reflective, intuitive verbal and global respectively.

Despite the difficulty in comparing the results of each study, due to the different approaches that the questionnaires have, it is possible to corroborate, that regardless of the instrument used, LS are dynamic [75] and can vary depending on multiple factors, such as age, academic year, country, culture, and teaching modality [76,77]. It has been previously stated that the teaching strategies must be adapted to the LS of the respective courses in which teaching is carried out [5,6]. However, it is currently questionable since favorable results have not really been seen when carrying out this adaptation of methodological strategies to LS [78,79]. Approaches to teaching assistance to students should focus on students applying LS questionnaires so that they know their respective style and thus can make the most of their resources, through advice and guidance. On the other hand, teachers must know the different LS as well as the theories that support them, so as not to use methodological strategies that focus on a single LS [80]. On the contrary, understanding LS should help teachers to develop multimodal learning approaches more than in individualized approaches to encourage deeper learning in students [7].

This is the first review that analyzes the prevalence of types of LS in undergraduate dentistry students. Among the limitations, the analyzed studies do not examine the same educational levels, the sample size of each study varies and because of the variety of instruments used, comparisons between studies that did not use the same instrument is difficult. On the other hand, not all the included studies present demographic data such as gender, age and year of the data extraction or do so in an incomplete manner, this is important to define which generation of students are represented, because it has been documented that generation X students (born between 1965 and 1980), generation Y, also called millennials (born between 1981 and 1994) and generation Z (born between 1995 till today) have different learning approaches preferences. Generation X students are described as independent, with the ability to self-direct, open-minded and obedient to authority, millennials are described as technologically competent, capable of doing multiple jobs and with a preference for collaborative work, meanwhile generation Z students are digital natives who prefer independent, more visual and kinesthetic LS and who report a strong use of technology as a consultation tool. It has been suggested that the teacher of Generation Z students should encourage the development of a dynamic and attractive learning environment that allows them to connect with their technological skills, for example, using Power Point presentations enhanced with audio, video analysis, infographics, virtual simulations, clinical care, among others, all of these resources ideally directed into short, precise activities with clear objectives for students. Complementary to the above, teachers must be compassionate and be able to create an enriching environment based on attributes such as respect, transparency, and accessibility [4,81].

5. Conclusion

This review was able to identify trends regarding LS preferences among UDS, despite the heterogeneity of the included studies. The analysis of the primary studies reviewed shows that in initial and pre-clinical dentistry students, LS are mostly *unimodal* and *theoretical*, according to the VARK and CHAEA, respectively. On the other hand, the analysis shows in clinical students, LS that are mostly *multimodal*,

Table 9

Summary of studies reporting LS in USD, using ILS.

Author	Processing		Perceiving		Receiving		Understanding		Total
	Active	Reflective	Sensitive	Intuitive	Visual	Verbal	Sequential	Global	
Kaczmarek et al. [67]	62	18	69	11	66	14	52	28	80
Baherimoghdam et al. [69]	45	40	61	24	72	13	54	31	85
	107	58	130	35	138	27	106	59	165
%	64,8	35,2	78,8	21,2	83,6	16,4	64,3	35,7	100

divergent, reflector and active-sensitive-visual-sequential, according to VARK, LSI, CHAEA and ILS. This dynamism in LS in the different stages of dental training could be influenced by the different methodological strategies used in the initial courses compared to those used in the intermediate and final courses of the degree, as they progress from pre-clinical to clinical practice, in which they must achieve a deeper understanding of their knowledge to perform diagnoses, prognoses and treatment plans. Knowing the different LS contributes to a greater empathy of teachers towards students and seeks the achievement of deeper learning, considering the diversity found in the classrooms, while encouraging the use of multiple approaches to learning. All fundamental aspects student centered-learning.

Scientific field of dental Science

Dental education.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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