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Effectiveness of case-based learning in Chinese dental education: a systematic review and meta-analysis

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ABSTRACT

Objective The application of case-based learning (CBL) pedagogy has been emerging as an improved and more practical learning method across the Chinese dental education system. This article provides a critical overview of CBL pedagogy and further assesses the effectiveness of this teaching model in Chinese dental education.

Design A systematic review and meta-analysis.

Methods Studies published up to December 2019 were searched in the following electronic databases: China National Knowledge Infrastructure, China Science Periodical Database, Chinese Biomedical documental database, Wanfang data, PubMed, EMBASE and Cochrane Central Register of Control Trials. All randomised controlled trials (RCTs) that compared the effectiveness of the CBL teaching model and the traditional lecture-based learning (LBL) model in all dental disciplines were included. The assessment of methodological quality was based on the guidelines described in the Cochrane Handbook for Systematic Reviews, and the meta-analysis was performed using the software RevMan V.5.3

Results A total of 30 RCTs were finally included, with a total sample size of 2356 dental students. The CBL pedagogy significantly increased knowledge scores (standardised mean difference (SMD)=1.58, 95% CI: 0.95 to 2.20, p<0.0001), skill scores (SMD=1.22, 95% CI: 0.34 to 2.11, p<0.0001), comprehensive ability scores (SMD=1.91, 95% CI: 1.74 to 4.07, p<0.0001) and teaching satisfaction (risk ratio=1.38; 95% CI: 1.15 to 1.65; p=0.01) compared with the LBL teaching model among the dental students. Additionally, a subgroup analysis showed significant differences in the effects of CBL on knowledge scores, skill scores and comprehensive ability scores when comparing theoretical and practical courses.

Conclusions The meta-analysis and systematic review of the eligible literature showed that the CBL pedagogy in Chinese dental education is an effective way to increase knowledge scores, skill scores, comprehensive ability scores and teaching satisfaction. Successful adaptation of this teaching model could solve the scarcity of highly skilled and professional dentists in dental schools and hospitals across China.

INTRODUCTION

Dental education typically exploits the conventional methods of didactic, discipline-based curricula to increase students'

Strengths and limitations of this study

► This is the first systematic review and meta-analysis of case-based learning (CBL) practice in Chinese dental education.

► It gives us some beneficial proposal to implementing the CBL pedagogy in future.

► The included studies were research in the field of medical education, so it is impossible for the researchers to implement allocation concealment and blinding.

► Methodology qualities of the included studies represent a major limitation of this review.

► Measurement bias exists in this review, for there is no standard criterion for evaluating the effectiveness of the CBL pedagogy in the included studies.

competency with those skills and professional values in a subject-centred matter.[1] The traditional didactic lecture-based curriculum uses an instructor-centred classroom setting in which students are passive listeners rather than active learners. Hence, the effectiveness of such teaching methods in equipping the graduates with a broad range of essential dental competencies, such as critical thinking and treating the patients comprehensively, is questionable. Notably, surveys in faculty members have reported that in most cases, graduate students could not efficiently implement their didactic preclinical knowledge into the actual clinical application when it comes to patient care.[2] As a result, long-established case-based learning (CBL) pedagogy, which originated from Harvard Medical School in the 1920s, has emerged as an effective teaching model innovation in health professional education, including dental education.

CBL methods generally focus on using wide ranges of medical and clinical cases to teach students about actual patient care situations. In these curricula, the teachers mainly guide the students to implement their acquired

knowledge foundation in making decisions on problems that they may encounter in practice. So, the student–teacher relationship goes on like that, the students take on the learning responsibilities by analysing the given case and designing effective treatment strategy, while the teacher's role is a prompter and guide to help students justify their analyses. The implementation process of CBL can be summarised as follows: establishment of the case → case grouping and analysis → brainstorming → identifying instruction goals → new findings → exchanging results between groups → reaching learning consensus and integrating the consensus into clinical practice.[3] CBL is increasingly becoming a popular teaching model applied in dental education in Europe, the USA, Canada, Australia and New Zealand since the 1990s, and some studies in these regions suggested that CBL is more effective in fostering deep learning, and efficient retention of analytical and diagnostic knowledge among students.[4] CBL may also facilitate competency development in students in a manner that parallels their future professional career goals.[5]

In the early 21st century, the Chinese dental education system realised the crucial systemic obstructions in transforming a dental graduate into a skilled and professional dentist who was in great demand. To overcome this roadblock, some of the well-known key Chinese dental schools, including Shanghai Second Medical University, School of Stomatology at the Fourth Military Medical University and School of Stomatology at Wuhan University, took critical steps forward to greatly reform the contemporary dental education models. These models included the most effective teaching concepts and were already being applied in diverse educational strategies, like CBL pedagogy. For the past 20 years, the CBL curriculum has been gradually adopted by several more dental schools across China, subsequently presenting its increasing success rates. In general, CBL curricula cover nearly all dental disciplines, including oral medicine, periodontology, prosthodontics, paediatric dentistry, orthodontics, preclinical training, etc. This kind of broad application of CBL methodology in the Chinese dental education system has been vividly reflected in the increasing number of publications of medical studies focusing on the CBL teaching model in China. Thus, this meta-analysis aimed to systematically review the effectiveness of CBL pedagogy performed in the Chinese dental education system. To evaluate the overall effectiveness, we performed subgroup analyses of the studies conducted in China to identify the benefits of the application of different types of courses in terms of knowledge scores, skill scores and comprehensive ability scores, as well as teaching satisfaction.

METHODS
Study design
The study methods used for this meta-analysis and systematic review were based on the recommended Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist guidelines.[6]

Search strategy
The published studies and trials were searched in the following Chinese electronic databases: China National Knowledge Infrastructure, China Science Periodical Database, Chinese Biomedical documental database and Wanfang data. Moreover, the following English-language electronic databases—PubMed, EMBASE and Cochrane Central Register of Controlled Trials—were searched. Next, the abstracts of the additional eligible studies posted in the international and national conference proceedings were also screened. The end date for all the electronic database searches was restricted to December 2019. The specific set of MeSH terms or keywords used to search the above databases was like ("case-based learning" OR "CBL") AND ("dental* OR dental* education OR dental* students") AND ("China"). There was no search restriction on language. Furthermore, the reference lists of these selected articles were reviewed for additional related reports.

Selection criteria
There were four inclusion criteria: (1) the studies were randomised controlled trials (RCTs); (2) the participants for the studies were undergraduate and graduate students of dental institutions in China; (3) the interventions included the CBL pedagogy in the experimental group covering all dental disciplines and traditional teaching methods (lecture-based learning, LBL) in the control group; neither the experiment nor the control group should be exposed to supplementary teaching methods that could have an impact on the results; and (4) the outcomes presented as data or descriptions of each RCT included at least one of the following scores: knowledge score, skill score, comprehensive ability score, pass rate and teaching satisfaction.

Any study which did not meet the above criteria was excluded. The titles and abstracts of all retrieved articles were independently reviewed by two reviewers (HD and CG) to identify potential studies. The full texts of the eligible studies were then obtained and assessed independently by the two reviewers. Any discrepancies were resolved by discussion with a third reviewer (LZ) until a consensus was met.

Data extraction
Data were collected and extracted by two independent reviewers (HD and CG) using a predefined data form, which included studies regarding basic characteristics, such as the first authors, year of publication, involved dental disciplines, characteristics and numbers of the participants, intervention methods and outcome measures. Any conflict on the eligibility of the extracted information by these two reviewers was resolved by discussion among themselves or intervention of the third reviewer.

Outcomes

The primary outcomes in this meta-analysis were knowledge scores, skill scores, comprehensive ability scores in the CBL group and the LBL group. The secondary outcomes were pass rate and teaching satisfaction. In the included studies, the teaching satisfaction was usually evaluated by a Likert scale. From 5 to 1, the decrease of the scores means the decline of satisfaction. When the scores were 5~4, teaching satisfaction was defined as significant. When the scores were 3~2, teaching satisfaction was defined as general. When the scores were 1, teaching satisfaction was defined as poor. Subgroup analyses were conducted to assess the benefits of applying CBL versus LBL to theoretical and practical courses in the above outcomes.

Quality assessment

The methodological qualities of the included studies were assessed as adequate, inadequate or uncertain independently by the two reviewers (HD and CG) using guidelines described in the Cochrane Collaboration for Systematic Reviews of Interventions.[7] Any disagreement was resolved through discussion. The quality assessment was based on six general sources of bias described as random sequence generation, allocation concealment, blinding, incomplete outcome data, selective reporting and other sources of bias contained in this specific study as the meaningful evaluation index. The overall methodological quality of each study was included as 'low risk of bias', 'high risk of bias' and 'uncertain risk of bias'. Information addressed by these items was retrieved from the published studies, and authors were contacted in case any additional information was needed.

Statistical analysis

Statistical analysis to test the heterogeneity of data and the meta-analysis was carried out using the Review Manager (RevMan) software (V.5.3, the Cochrane Collaboration, UK). For continuous outcomes, such as knowledge scores, skill scores, comprehensive ability scores, the standardised mean difference for effect size based on sample size and 95% CIs were calculated from the same scale. For dichotomous outcomes, such as pass rate and teaching satisfaction, the risk ratio (RR) and 95% CI were calculated. If the data could not be pooled, descriptive statistics were used only. Publication bias was tested independently using funnel plots of knowledge scores, skill scores, comprehensive ability scores and teaching satisfaction; if the funnel plot was symmetric, there was a low potential for publication bias, and vice-versa.

Role of the funding source

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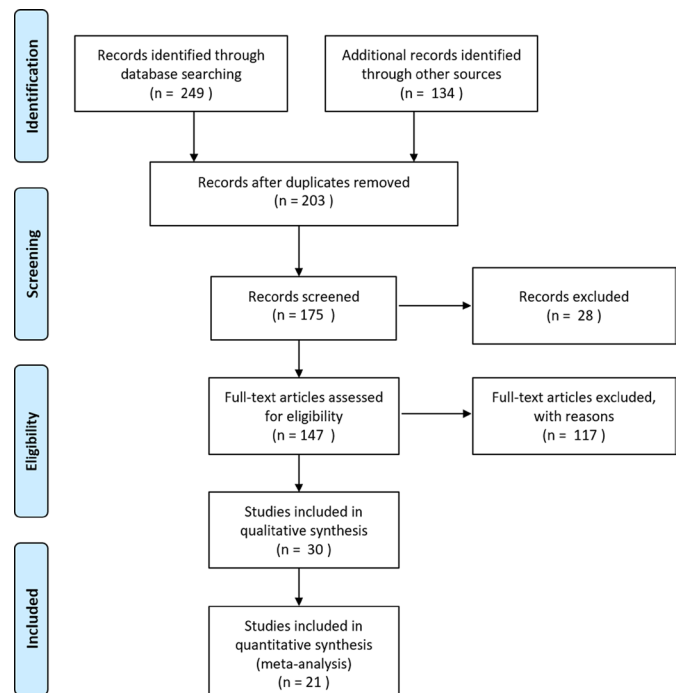

Figure 1 Flow diagram of study selection (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

writing of the report; and in the decision to submit the paper for publication.

Patient and public involvement

Since this is a systematic review and meta-analysis, patients and the public were not involved in the design or planning of the study.

RESULTS
Search results

The details on study inclusion and exclusion are summarised in the flow diagram (figure 1). The literature search in the databases yielded a total of 383 studies in the initial search, out of which 167 records were removed as duplicates, resulting in 216 records. After applying the selection criteria, 175 records were selected. Based on their titles and abstracts, a further 28 studies were excluded because some were experience summaries, and others were questionnaire surveys without theoretical measurement of the scores. The full texts of the remaining 147 studies were reviewed, and the additional 117 records were also excluded since they were trials without controls or CBL combined with supplementary teaching methods. Thus, a total of 30 studies,[8–37] involving pooled 2356 dental graduate students, met the inclusion criteria, which were subsequently selected for this meta-analysis. All of the included studies were published between 2008 and 2019. These studies included 1198 students in the CBL teaching group and 1158 students in the LBL group. In these cohorts, most of the participating students were seniors. The sample size in the included trials ranged from 20 to 200 participants. Among these 30 studies, 1

Table 1 Characteristics of the included studies

Author	Year	Study design	No of CBL	No of LBL	Grade	Course name	Course type	Outcome measures
Zuo et al[8]	2011	RCT	43	43	Senior	Prosthodontics	Theory course	KS, TS
Xia and Sui[9]	2012	RCT	56	56	Junior	Oral and maxillofacial aesthetic surgery	Theory course	KS, TS
Dou et al[10]	2012	RCT	16	15	Senior	Endodontics	Practice course	KS, SS, CAS, TS
Jiang[11]	2019	RCT	110	116	Senior	Prosthodontics	Practice course	KS
Shi et al[12]	2015	RCT	37	37	Senior	Orthodontics	Theory course	KS, SS, CAS, TS
Wang[13]	2018	RCT	100	100	Senior	General dentistry	Theory course	KS, SS, CAS, TS
Liu et al[14]	2012	RCT	61	30	Junior	Oral anatomy and physiology	Theory course	KS
Wang et al[15]	2011	RCT	70	70	Junior	Oral histology and pathology	Theory course	KS, TS
Liang et al[16]	2008	RCT	49	50	Junior	Oral histology and pathology	Theory course	KS, TS
Wang et al[17]	2015	RCT	30	30	Senior	General dentistry	Theory course	KS, TS
Lu et al[18]	2012	RCT	76	65	Senior	Periodontology	Theory course	KS, TS
Wu et al[19]	2014	RCT	45	44	Senior	Prosthodontics	Theory course	KS, TS
Zhang[20]	2016	RCT	42	42	Senior	Orthodontics	Theory course	KS, SS, CAS, TS
Lu et al[21]	2012	RCT	72	69	Senior	Periodontology	Practice course	KS, SS, CAS, TS
Zuo et al[22]	2015	RCT	15	15	5th-year student	General dentistry	Practice course	KS, SS, CAS, TS
Zhao et al[23]	2016	RCT	39	39	5th-year student	General dentistry	Practice course	KS, SS
Wang et al[24]	2019	RCT	15	15	Senior	Endodontics	Practice course	CAS
Yang et al[25]	2015	RCT	20	20	Senior	Prosthodontics	Theory course	KS, CAS
Chen[26]	2019	RCT	25	25	Senior	Prosthodontics	Theory course	KS, CAS, TS
Liao[27]	2018	RCT	10	10	Senior	Prosthodontics	Theory course	KS, TS
Tao et al[28]	2011	RCT	30	30	5th-year student	General dentistry	Practice course	KS, TS
Liu et al[29]	2013	RCT	20	21	Senior	Endodontics	Practice course	KS, SS, CAS, TS
Hu et al[30]	2019	RCT	22	21	Senior	Periodontology	Practice course	KS, TS
Huang et al[31]	2014	RCT	30	30	Master	Orthodontics	Practice course	SS
Yu et al[32]	2018	RCT	30	30	Senior	Orthodontics	Theory course	KS, CAS, TS
Wei et al[33]	2015	RCT	40	40	Senior	Prosthodontics	Theory course	KS, CAS, TS
Sun et al[34]	2019	RCT	15	15	Senior	Endodontics	Practice course	KS, CAS, TS
Yang et al[35]	2018	RCT	20	20	Senior	Periodontology	Practice course	KS, SS, TS
Li et al[36]	2015	RCT	40	40	Senior	Oral and maxillofacial aesthetic surgery	Theory course	KS, SS, CAS, TS
Du et al[37]	2013	RCT	20	20	Senior	Oral medicine	Theory course	KS

CAS, comprehensive ability scores; CBL, case-based learning; KS, knowledge scores; LBL, lecture-based learning; No, number; RCT, randomised controlled trial; SS, skill scores; TS, teaching satisfaction.
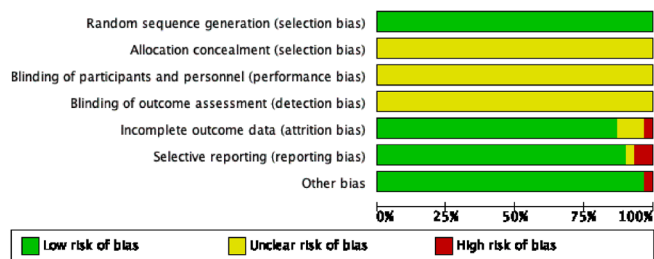
Figure 2 Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

study[37] was published in English, and the others were published in Chinese. The types of dental disciplines included in the studies were prosthodontics,[8 11 19 26–28 33] endodontics,[10 25 30 34] periodontology,[18 21 31 35] orthodontics,[12 20 32] oral medicine,[37] general dentistry,[13 17 22 27] oral and maxillofacial aesthetic surgery,[9 36] oral anatomy and physiology,[14] and oral histology and pathology.[15 16] There were 18 RCTs[8 9 12–20 26–28 32 33 35 37] on theoretical courses, and 12 RCTs[10 11 21–25 29–31 34 36] on practical courses. The basic characteristics of the 30 included studies are presented in table 1.

The quality of the 30 studies was evaluated using the Cochrane Collaboration Handbook for Systematic Reviews. There were eight studies[13 20 26 28 31 34 35 37] reporting the detailed information of the randomisation sequence generation, all of which were generated using the randomised number chart. However, none of the studies reported the allocation concealment methods and

blinding. The summary of the methodological quality of each study is shown in figure 2. The meta-analysis independently used funnel plots of knowledge scores, skill scores, comprehensive ability scores and teaching satisfaction to assess publication bias (figure 3A–D). The shape of the funnel plot was nearly symmetrical, indicating negligible evidence of significant publication bias.

Measurements of knowledge scores

Twenty-six of the included studies reported relevant data regarding knowledge scores. Among these, four studies[11 16 17 28] reported dichotomous data, such as pass rate, excellence rate and improvement rate. Because of the diversity-mediated heterogeneity of data, the outcomes were not pooled. The remaining 22 studies[8–22 24 25 27 28 30–32 36 37] reported the continuous data, such as mean scores and SD, which were pooled in this meta-analysis (904 and 857 students in the CBL and LBL groups, respectively). The meta-analysis of the knowledge scores found that the CBL pedagogy significantly increased the knowledge scores by a mean of 1.58 compared with that of LBL pedagogy (95% CI: 0.95 to 2.20; p<0.00001). The random-effects model was used for the meta-analysis because of the higher heterogeneity of the data (p<0.00001, I^2=97%) (figure 4).

Measurements of skill scores

Eight studies[10 21 23 29 31 34–36] documented relevant data regarding skill scores (252 and 249 students in the CBL and LBL groups, respectively). The meta-analysis of the skill scores found that the CBL pedagogy significantly
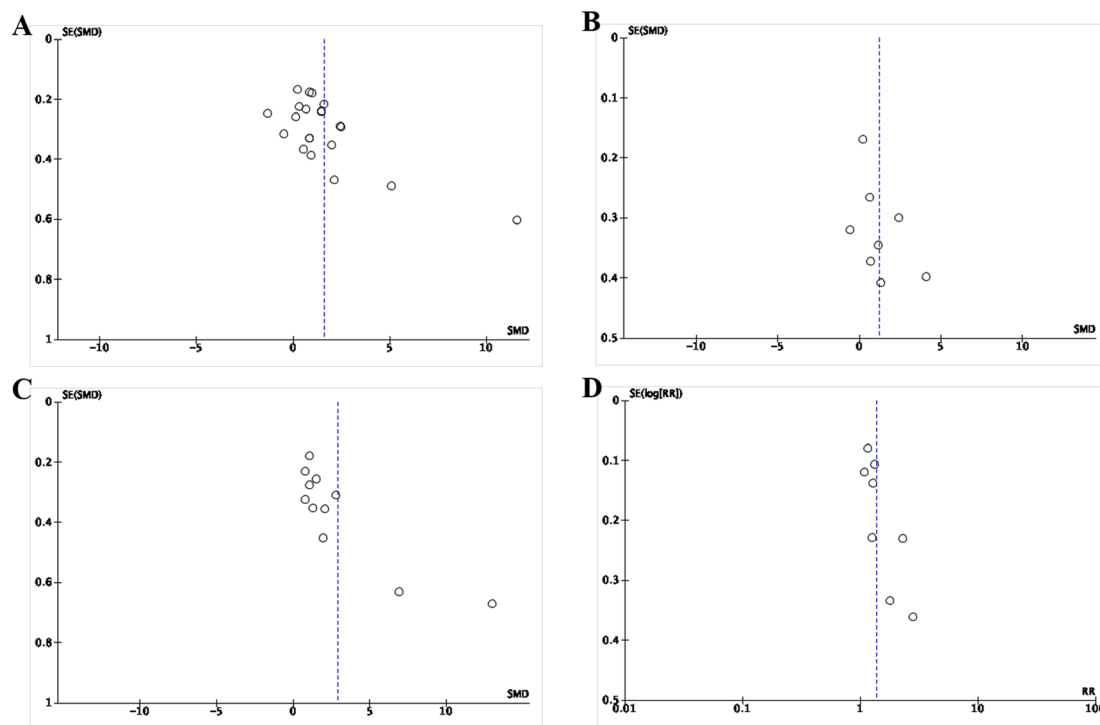

Figure 3 Funnel plots for publication bias. (A) Publication bias of knowledge scores; (B) publication bias of skill scores; (C) publication bias of comprehensive ability scores; (D) publication bias of satisfactory teaching effect. RR, risk ratio; SMD, standardised mean difference.
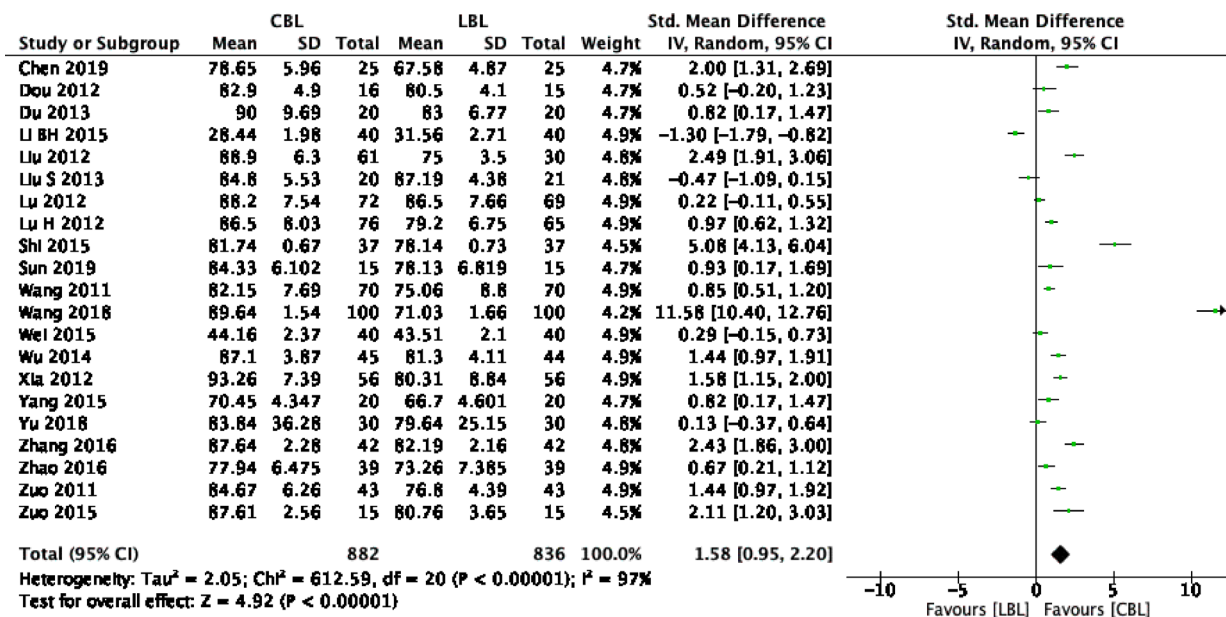
Study or Subgroup	CBL Mean	SD	Total	LBL Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Chen 2019	78.65	5.96	25	67.58	4.87	25	4.7%	2.00 [1.31, 2.69]
Dou 2012	82.9	4.9	16	80.5	4.1	15	4.7%	0.52 [−0.20, 1.23]
Du 2013	90	9.69	20	83	6.77	20	4.7%	0.82 [0.17, 1.47]
Li BH 2015	28.44	1.98	40	31.56	2.71	40	4.9%	−1.30 [−1.79, −0.82]
Liu 2012	86.9	6.3	61	75	3.5	30	4.8%	2.49 [1.91, 3.06]
Liu S 2013	84.8	5.53	20	87.19	4.38	21	4.8%	−0.47 [−1.09, 0.15]
Lu 2012	88.2	7.54	72	86.5	7.66	69	4.9%	0.22 [−0.11, 0.55]
Lu H 2012	86.5	8.03	76	79.2	6.75	65	4.9%	0.97 [0.62, 1.32]
Shi 2015	81.74	0.67	37	78.14	0.73	37	4.5%	5.08 [4.13, 6.04]
Sun 2019	84.33	6.102	15	78.13	6.819	15	4.7%	0.93 [0.17, 1.69]
Wang 2011	82.15	7.69	70	75.06	8.8	70	4.9%	0.85 [0.51, 1.20]
Wang 2018	89.64	1.54	100	71.03	1.66	100	4.2%	11.58 [10.40, 12.76]
Wei 2015	44.16	2.37	40	43.51	2.1	40	4.9%	0.29 [−0.15, 0.73]
Wu 2014	87.1	3.87	45	81.3	4.11	44	4.9%	1.44 [0.97, 1.91]
Xia 2012	93.26	7.39	56	80.31	8.84	56	4.9%	1.58 [1.15, 2.00]
Yang 2015	70.45	4.347	20	66.7	4.601	20	4.7%	0.82 [0.17, 1.47]
Yu 2018	83.84	36.28	30	79.64	25.15	30	4.8%	0.13 [−0.37, 0.64]
Zhang 2016	87.64	2.28	42	82.19	2.16	42	4.8%	2.43 [1.86, 3.00]
Zhao 2016	77.94	6.475	39	73.26	7.385	39	4.9%	0.67 [0.21, 1.12]
Zuo 2011	84.67	6.26	43	76.8	4.39	43	4.9%	1.44 [0.97, 1.92]
Zuo 2015	87.61	2.56	15	80.76	3.65	15	4.5%	2.11 [1.20, 3.03]
Total (95% CI)			882			836	100.0%	1.58 [0.95, 2.20]

Heterogeneity: Tau² = 2.05; Chi² = 612.59, df = 20 (P < 0.00001); I² = 97%
Test for overall effect: Z = 4.92 (P < 0.00001)

Figure 4 Forest plot of knowledge scores for CBL compared with LBL. CBL, case-based learning; LBL, lecture-based learning.

increased skill scores by a mean of 1.22 compared with that of LBL teaching model (95% CI: 0.34 to 2.11; p<0.0001). The random-effects model was used for the meta-analysis because of the higher heterogeneity of the data (p<0.00001, I²=95%) (figure 5).

Measurements of comprehensive ability scores

Eleven studies[12 13 20–22 24–26 29–32] produced relevant data regarding comprehensive ability scores (441 and 439 students in the CBL and LBL groups, respectively). The meta-analysis of the comprehensive ability scores found that the CBL teaching model significantly increased comprehensive ability scores by a mean of 2.91 compared with that of the LBL teaching model (95% CI: 1.74 to 4.07; p<0.0001). The random-effects model was used for the meta-analysis because of the higher heterogeneity of the data (p<0.0001, I²=98%) (figure 6).

Measurements of teaching satisfaction

Teaching satisfaction was divided into three dimensions: satisfactory teaching effect, general teaching effect and poor teaching effect. A total of eight studies[10 13 15–17 28 30 36] reported relevant data regarding

satisfactory teaching effects (340 and 340 students in the CBL and LBL groups, respectively). The meta-analysis of satisfactory teaching effect on the CBL teaching model found higher satisfactory rates compared with that of the LBL teaching model (RR: 1.38; 95% CI: 1.15 to 1.65; p=0.01). The random-effects model was used for the meta-analysis because of the higher heterogeneity of the data (p=0.01, I²=68%) (figure 7). There were no complete data to pool the general teaching effect and poor teaching effect between the CBL and LBL groups.

Subgroup analysis

Subgroup analysis was performed to examine the differences between practical and theoretical courses when CBL was applied instead of LBL methods. Table 2 shows the results of the subgroup analysis. The outcome revealed that there were significant differences in the effects of CBL on knowledge scores, skill scores and comprehensive ability scores when comparing theoretical and practical courses. In addition, a subgroup analysis of the level of training showed that the CBL teaching model also
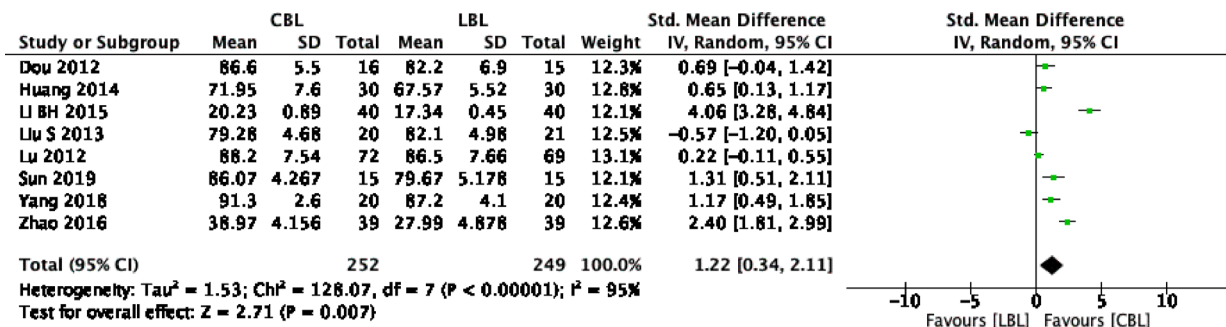
Study or Subgroup	CBL Mean	SD	Total	LBL Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Dou 2012	86.6	5.5	16	82.2	6.9	15	12.3%	0.69 [−0.04, 1.42]
Huang 2014	71.95	7.6	30	67.57	5.52	30	12.8%	0.65 [0.13, 1.17]
Li BH 2015	20.23	0.89	40	17.34	0.45	40	12.1%	4.06 [3.28, 4.84]
Liu S 2013	79.28	4.68	20	82.1	4.98	21	12.5%	−0.57 [−1.20, 0.05]
Lu 2012	88.2	7.54	72	86.5	7.66	69	13.1%	0.22 [−0.11, 0.55]
Sun 2019	86.07	4.267	15	79.67	5.178	15	12.1%	1.31 [0.51, 2.11]
Yang 2018	91.3	2.6	20	87.2	4.1	20	12.4%	1.17 [0.49, 1.85]
Zhao 2016	38.97	4.156	39	27.99	4.878	39	12.6%	2.40 [1.81, 2.99]
Total (95% CI)			252			249	100.0%	1.22 [0.34, 2.11]

Heterogeneity: Tau² = 1.53; Chi² = 128.07, df = 7 (P < 0.00001); I² = 95%
Test for overall effect: Z = 2.71 (P = 0.007)

Figure 5 Forest plot of skill scores for CBL compared with LBL. CBL, case-based learning; LBL, lecture-based learning.
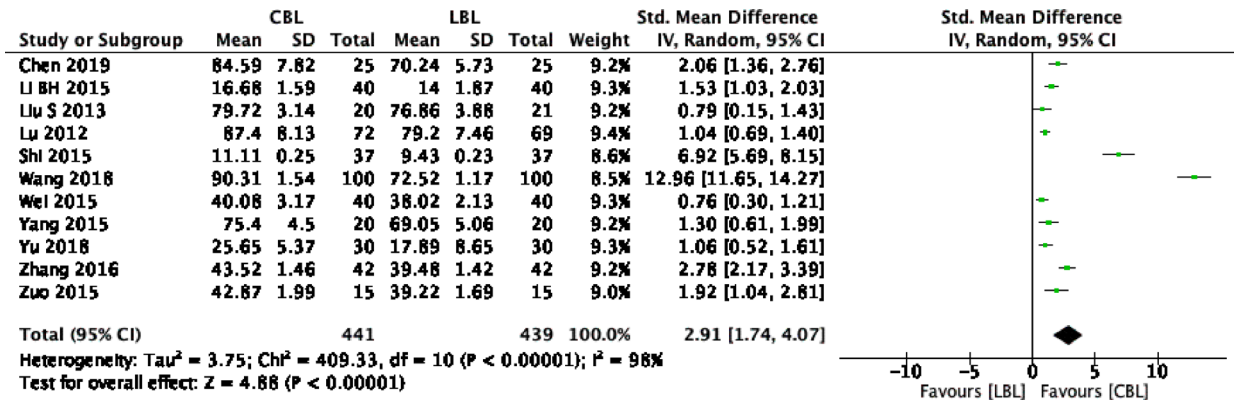
Figure 6 Forest plot of comprehensive ability scores for CBL compared with LBL. CBL, case-based learning; LBL, lecture-based learning.

significantly improved the knowledge scores of senior and 5th-year students (table 3).

DISCUSSION

Since the beginning of the 21st century, worldwide medical education, including dentistry, has increasingly emphasised the development of realistic clinical competencies as well as educational milestones of the graduates. The definition of competency in dentistry has been made by the working party of the Competencies for Dental Licensure in Canada as, 'competency is most often used to describe the skills, understanding and professional values of an individual ready to begin independent dental or allied oral health care practice'.[38] At the professional level, the Commission on Dental Accreditation proposed that dental students' competencies should include critical thinking and acquisition of evidence-based information in clinical reasoning and problem-solving.[39] CBL pedagogy, as an important element of competency-based education, typically focuses on the discussion of a patient case, and the fundamental concepts required for understanding the case are presented via lectures and/or readings before conducting case discussion. In these courses, teachers become a critical guide in assisting students in enriching their dynamic thought processes rather than passively acquiring information. CBL has been emerging

as an outstanding start to transit students from more traditional and theoretical 'textbook'-oriented methodologies to practical scenarios. This unique academic concept enables students to think holistically, starting from presenting the medical history and diagnostics to the social aspects of the patient's quality of life during and after the course of treatments. This teaching strategy has shown to increase the students' interest to learn deeply about the realistic clinical practice and also prepares the students with a mindset to work in an interdisciplinary group, the advantages of which can then be seen to amplify further replenishing the deficiency of highly skilled dentists.

Unlike developed countries, CBL has not been a routine pedagogy in Chinese dental education. There have been certain inhibitory factors against the broad-spectrum implementation of CBL in China. First, the traditional teacher-centred model has been dominating the dental education system in China for decades, which has almost established predefined educational experiences for both the students and teachers. Hence, it is evident that there will be a long-term adaption period to adjust the CBL teaching pattern and assessment system for both the teachers and students. Second, the levels and standards of dental education vary dramatically among different schools in China. The scarcity of high-quality
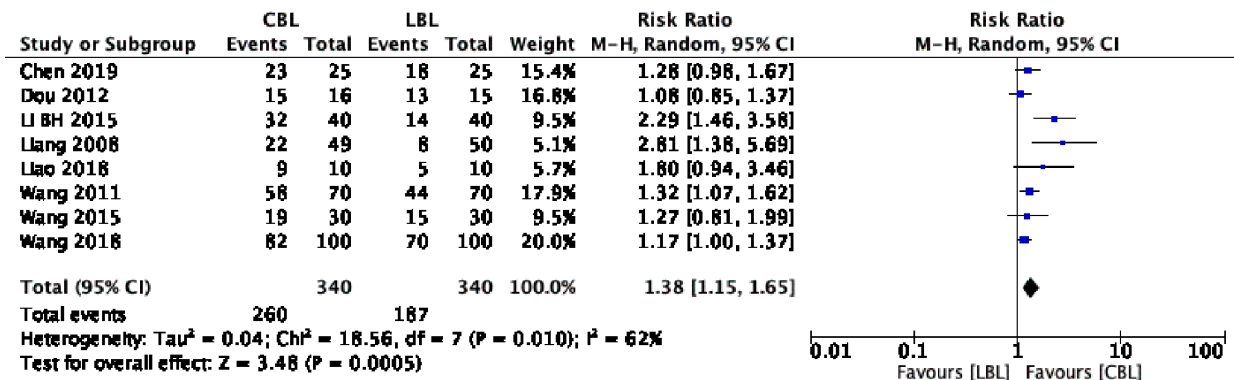

Figure 7 Forest plot of teaching satisfaction for CBL compared with LBL. CBL, case-based learning; LBL, lecture-based learning.

Table 2 Results of subgroup analyses in the current meta-analysis

Items	No of participants			P value	Incidence			Model
	Studies	CBL	LBL		SMD/RR	95% CI	Heterogeneity (I²)	
Knowledge scores*								
Theoretical courses	14	656	651	<0.0001	1.78	0.95 to 2.62	97%	Random
Practical courses	7	226	185	<0.0001	1.1	0.34 to 1.86	91%	Random
Skill scores*								
Theoretical courses	2	40	40	<0.0001	4.06	3.28 to 4.84	NS	Random
Practical courses	6	212	209	0.02	0.83	0.15 to 1.51	90%	Random
Comprehensive ability scores*								
Theoretical courses	7	309	309	<0.0001	3.81	1.88 to 5.74	98%	Random
Practical courses	4	132	130	0.01	1.39	0.82 to 1.97	72%	Random
Teaching satisfaction†								
Theoretical causes	6	293	294	<0.0001	2.63	1.78 to 3.91	65%	Random
Practical courses	2	47	46	0.0001	6.31	2.47 to 16.13	NS	Random

*Values presented as mean difference and 95% CI.
†Values presented as RR and 95% CI.
CBL, case-based learning; LBL, lecture-based learning; No, number; NS, non-significant; RR, risk ratio; SMD, standardised mean difference.

and energetic teaching teams is a significant inhibitory factor against the successful implementation of the CBL pedagogy. Third, the CBL curricula should be based on the sound fundamental knowledge background of the students. Notably, dental students in China usually have to complete the multidisciplinary dental courses including restorative dentistry, preventive dentistry, periodontology, prosthodontics, paediatric dentistry and oral medicine within 1–1.5 years of course duration, which is totally different from the dental education patterns in developed countries, such as the USA.[40] The time limitations make dental schools employ less time-consuming teaching models to fit well within the scheduled period. Hence, a great deal of educational reformation, rearrangement, and successful integration between academia and professional hospitals are urgently required to vividly improve the Chinese dental education system.

The key findings of this meta-analysis suggested that the CBL pedagogy could significantly increase knowledge scores, skill scores, comprehensive ability scores and teaching satisfaction compared with that of the traditional LBL teaching model. Subgroup analyses also consistently demonstrated that the knowledge scores and comprehensive ability scores between practical and theoretical courses were significantly different, and satisfactory teaching effects in practical courses were significant. According to the questionnaire-based surveys of the students, CBL aroused their learning enthusiasm, trained them to improve their critical thinking ability, brought their interests toward working as a team, and enabled them to integrate and manage learning resources effectively and actively, and promoted self-study capacity.

As we know, this is the first systematic review and meta-analysis of CBL practice in Chinese dental education. Compared with other reviews on teaching methods reform in Chinese dental education previously, such as meta-analysis on problem-based learning practice in Chinese dental education published by Huang *et al*,[40] the present study had two strengths. First, a subgroup analysis

Table 3 Subgroup analyses of the level of training in the current meta-analysis

Items	No of participants			Incidence				Model
	Studies	CBL	LBL	P value	SMD/MD	95% CI	Heterogeneity (I²)	
Knowledge scores*								
Junior	4	263	231	0.11	0.82	−0.17 to 1.82	96%	Random
Senior	22	686	671	0.001	1.53	0.75 to 2.31	97%	Random
5th-year student	3	82	82	0.007	1.05	0.29 to 1.81	81%	Random

*Values presented as MD and 95% CI.
CBL, case-based learning; LBL, lecture-based learning; MD, mean difference; No, number; SMD, standardised mean difference.

was performed comparing the course type between the theoretical courses and the practical courses. Second, this study independently used funnel plots to assess publication bias. The plots were generally symmetrical and showed a lower publication bias.

However, there were also several limitations in the present study. The methodology qualities of the included RCTs were not significantly high. None of them reported the allocation concealment and blinding sources. There was significant heterogeneity of the data among the 22 pooled studies with respect to knowledge scores, the 8 pooled studies with respect to skill scores and the 11 pooled studies with respect to comprehensive ability scores. The following factors might have led to these diversities: (1) the pooled studies focused on different dental disciplines; (2) the heterogeneity of the reported results, including knowledge scores and skill scores, was significantly high; (3) there were no guidelines to implicate CBL for different disciplines; (4) there were no standard criteria for the evaluation of the teaching effect of CBL pedagogy. Therefore, more scientifically designed RCTs in this field will be needed in the future to address these issues.

To better apply and study the CBL teaching model in Chinese dental education background, first, teachers should design an effective teaching programme based on teaching experiences that could facilitate and improve the students' ability to think critically and treat patients comprehensively on the basis of their sound fundamental knowledge of the dental sciences; second, teachers should develop or select realistic intriguing cases which link theoretical knowledge to practical aspects through inquiry-based learning methods, and simulate scenarios by simultaneously taking into account the patient's medical, dental, psychological, socioeconomic and cultural conditions; third, the teaching method of CBL is a three-dimensional cooperative relationship, which includes the dominant relationships between teachers and students, among students, and between virtual and realistic patient–doctor scenario. In the CBL teaching model, students are placed at the centre of the educational teaching network. Students should be engaged in multimodal activities such as information-gathering, higher-order analytical thinking, synthesis and evaluation of the case-specific treatment strategy. In this way, the CBL curriculum would stimulate students' active learning capacity, and help them demonstrate the equivalent or superior preparation skills for key competencies compared with the requirements in their day-to-day professional life. Future studies should aim to assess the impact of the CBL on students' outcomes and to develop a better understanding of their learning experiences within the CBL framework in comparison with those they have during didactic courses.

In summary, this meta-analysis revealed that the CBL pedagogy could be an effective method for increasing the knowledge scores, skill scores, comprehensive ability scores, as well as toward improving teaching satisfaction among the dental graduates in China. CBL appears to be superior to traditional lecture-based teaching methods. Thus, the use of the CBL teaching model may be optimal for improving dental education in China. However, the heterogeneity of the data from the included studies and the relatively low qualities of statistically validated measures should be taken into account in future practice, suggesting an urgent necessity for high-quality studies to efficiently assess the effectiveness of CBL pedagogy in the Chinese dental education system.

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