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A Literature Review of the Predictive Validity of European Dental School Selection Methods

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Abstract

Introduction

Selection to dental school is the point at which there is the potential to assess a wide range of candidate attributes and select those most likely to learn, train and work within the profession. Despite this, little is known in terms of what works and what does not work in dental selection in terms of predicting future performance accurately and fairly. Given this, our aim was to synthesize the last 30 years of research investigating the predictive validity of dental school selection methods.

Methods

A search of the electronic databases SCOPUS, Pubmed and Embase was conducted. Results were limited to English language studies published between January 1987 and January 2017.

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Results

21 studies were included. Selection tools fell into five broad categories: tests of personal qualities; cognitive ability; academic attainment; psychomotor skills and combined ability tests. Most were retrospective, single site studies limited to early years of dental school. Weak correlations were reported but in most cases these were between small sections of the selection tool and/or the outcome measure.

Discussion

There was a notable dearth of published research examining dental schools selection processes across Europe over the last 30 years. Current literature was limited by weak study design and lack of long term follow up.

Conclusion

There is insufficient high quality evidence from which to draw any conclusions as to the best selection methods to use in dental school selection. Without this, designing selection frameworks for dentistry which are appropriately weighted, reliable and valid remains a challenge.

Introduction

Selection to dental school is the point at which there is the potential to assess a wide range of candidate attributes and select those most likely to learn, train and work within a profession for which they have a particular aptitude¹. Once admitted to dental school approximately 98% of students graduate and work as dentists^{2,3}. Selection and dental school training thus appears to be effective at getting students to the point of graduation and early career posts. However evidence of effectiveness of selection in terms of selecting dentists who continue to make a positive contribution to their profession and the public they serve after graduation is less convincing⁴.

A scoping exercise indicated that within Europe prior academic attainment, used either in isolation or in combination with a personal statement, references and interviews, remains the main method of admission to dental school⁵⁻²⁴. This is in contrast to countries such as the USA²⁵, Canada²⁶ and Australia²⁷ who typically use a dental admissions test. More contemporary approaches still depend on prior academic attainment (usually performance on school examinations) as the first hurdle in the admissions process, but this may be followed by an admissions test, an interview and/or a manual dexterity test²⁸⁻³⁵. This reflects that seen in medical selection^{36,37} but, unlike medicine – and indeed higher education as a whole³⁸⁻⁴¹, selection, while a topic of discussion within dental education⁴²⁻⁴⁴, does not appear to be a major area of research activity within Europe. As a consequence, little is known in terms of what works and what does not work in dental selection in terms of predicting future performance accurately and fairly⁴⁵. This leaves dental schools open to criticism, and often unable to reassure key stakeholders that their approaches to selection do indeed select the “best” applicants.

A core concept in determining the effectiveness of a selection method is the validity of the selection tool. The concept of validity was formulated by Kelley⁴⁶ who stated that a test is valid if it measures what it claims to measure. For a brief overview of the different types of validity see table 1.

Predictive validity is the ability of a test or intervention to predict future performance and is therefore appropriate to examine in relation to whether or not dental school selection is effective⁴⁷.

We present here a synthesis of the results of the last 30 years of research investigating the predictive validity of dental school selection methods in Europe. Our aim in doing so is to inform future practice in dental student selection and outline a future research agenda.

Methods

This review was conducted in accordance to the PRISMA guidelines for systematic reviews⁴⁸. A search of the electronic databases SCOPUS, Pubmed and Embase was conducted in January 2017 using the MeSH terms 'Education', 'Dental', 'Criteria' and 'school admission' and equivalent free text searches for terms pertaining to dental education (school, university), criteria (methods, tools) and admission (selection, entrance). Further papers were also identified upon reading the full text of studies found in the electronic search. A flow diagram showing the process of investigation can be viewed at Figure 1.

Study selection

Results were limited to English language studies published in the 30 years between January 1987 and January 2017. Peer-reviewed papers and studies reporting empirical data relating to undergraduate dental education in Europe were included. We excluded non-European studies, general opinion pieces, commentaries and letters. The context for our exclusion criteria can be viewed in box 1.

Assessment of studies

All included studies were assessed first by CC and then collectively by all three authors. Study assessment included appraisal of study quality. Any disagreements were resolved by discussion.

Included papers were assessed with regards to: (1) selection method assessed (e.g. interview, aptitude test) and (2) study design (e.g., study type, site, population, statistical analysis and outcome measure). This data collection protocol was a modified version of that employed by a similar review of medical school selection criteria³⁷. A synthesis of the findings is provided below.

Data synthesis

On completion of the systematic search, it was apparent that the diverse nature of the study designs and outcome measures used would not lend themselves to a traditional systematic review. Several conditions are critical to sound meta-analysis or systematic review⁴⁹. The diversity of the selection methods, combination of methods, their application and different outcome measures meant studies could not be combined in any meaningful way^{50, 51, 52}. Thus, a narrative synthesis was the most appropriate way to synthesize the data. Narrative synthesis is a systematic process of making sense of evidence using a range of methods which relies primarily on the use of words and text to summarise and explain data⁵³.

Results

The search strategy yielded a total of 206 citations after the removal of duplicates. Following exclusion of studies that did not meet inclusion criteria, 21 studies remained. A summary table of the results can be view in Table 2. The results are presented under the following subsections:

general findings; selection tool used and predictive validity; research design used to validate selection practices; and outcome measures.

General Findings

The last 10 years yielded the highest rate of publication (n=14)^{5,28-34,54-59} while half as many (7) studies were published between 1997 and 2007^{35,60-65}. Most papers were from the UK (n=9)^{5,28,29,34,58,59,62,64,65} and reported studies from six different dental schools. Sweden provided four studies from two institutions^{30,35,61,63}, whilst the remaining studies were from Austria (n=2)^{33,54}, Belgium (n=2)^{32,56}, Germany (n=2)^{31,55}, Ireland (n=1)⁶⁰ and Italy (n=1)⁵⁷.

Outcome measures

Outcome measures varied significantly across all papers. Most authors used existing dental school assessments as an outcome measure^{5,28-31,54,55,58,59} and these were individual to each school. No detail was given in any of the papers as to the nature of these assessments, or their robustness in terms of psychometric properties⁶⁶. The majority of authors assessed if their selection methods predicted performance on knowledge-based exams^{5,28-35,54-56,58-60,64,65} regardless of whether the selection method was designed to measure academic attainment, or not (for example, comparing performance on psychomotor skills test with performance on a later knowledge-based exam). Table 3 describes the selection test focus and compares this with the focus of the outcome measure used along with whether the results found were significant. The reliability of the outcome measure was only reported by one author⁵⁹.

Selection tool used and Predictive Validity

The selection tools reported fell into five broad but distinct categories: tests of (1) personal qualities, also known as non-academic attributes (e.g. Interviews); (2) cognitive ability, (3) academic attainment, or knowledge; (4) psychomotor skills and (5) combined ability tests. Almost all authors reported on multiple tests^{28,30,33,35,55,56,58,59,61-63,67}.

Most found correlation between part^{5,28-31,54-56,60-62,64,65,67}, if not all³³, of the selection process employed and the outcome under study. However in most cases, the strength of relationship (r), evaluated using Cohen's conventions⁶⁸ (0.10 weak, 0.30 moderate, 0.5 strong), was a weak correlation between only part of the selection test or outcome measure (n=9)^{5,29,30,55,56,59-61,67}. In some cases correlations were reported between a section of an admission test^{5,29,30,61,64,65}, such as a single interview question, and/or small sections of the outcome measure^{28,30,31,54,55}, such as a single exam result. Three authors reported a negative correlation between the method of selection and their outcome measure^{28,31,58}.

A moderate correlation between selection test and dental school assessment was found by four authors in relation to the UKCAT²⁸, previous academic scores⁵, a non-structured interview⁵⁵ and a manual dexterity test⁶¹. However most authors found weak or no significant correlation between similar tests and their own outcome measures^{5,28,34,35,55,58-64}.

1. Personal qualities or non-academic attributes

Nine studies investigated tests of non-academic attributes^{28,29,34,55,58,59,62,64,65}, seven of these predicted outcomes^{28,29,55,59,62,64,65}

The predictive validity of interviews was reported by seven authors^{28,34,55,58,62,64,65}. Of these, four reported the use of unstructured interview formats^{55,62,64,65} (in one case with no interviewer training⁵⁵). Two reported the use of a semi-structured (predetermined topics) interview^{34,58}. One author reported a structured interview, employing a series of nine scenarios, of which each candidate was given three at random²⁸. Three papers reported that interview performance did predict outcome on knowledge-based assessments^{55,64,65} whereas two other papers^{30,34} reported they did not. Whether an interview was structured or not had no relation to the outcome found.

Two of the above authors also investigated the use of another non-academic attribute test alongside the interview^{28,58}. These are therefore added to the remaining two papers in this category^{29,59}. Three authors investigated the use of a multiple-mini interview^{29,58,59}, one author investigated the SJT component of the UKCAT (UK Clinical Aptitude Test)²⁸. One author additionally reported on a personal statement⁵⁹.

Of the three papers investigating the use of a multiple-mini interview^{29,58,59} Foley & Hijazi found correlation with GPA on knowledge based assessments throughout dental school ($r=0.136$ ⁵⁹, $r=0.1$ ²⁹), whereas McAndrew⁵⁸ found a negative correlation with assessment scores in year 1. In relation to the use of an SJT^{28,32} the one author investigating this reported no correlation with exam results in first year of dental studies²⁸. The use of a personal statement did not predict combined assessment scores throughout dental school⁵⁹.

2. Tests of cognitive ability

Three studies explored the use of the cognitive ability component of UKCAT^{5,28,59}. The UKCAT predicted grade point average throughout dental school ($r=0.077$)⁵⁹ in one study, but the remaining two studies found only partial correlation. Specifically, Lambe²⁸ found correlation with two of three knowledge based exams in first year ($r=0.32$, $r=0.38$) while Lala⁵ found correlation between a subsection of the UKCAT and first year exam performance (DA $r=0.203$).

3. Prior academic attainment & knowledge based exams

All studies applied prior academic attainment as an initial hurdle to application. Nine authors examined this^{55,59,60,62}, and/or a different test of knowledge as a variable in their results^{29,31,54,55,64}. Four authors investigated high school grade point average^{5,55,60,62}, one author investigated first degree results- for graduate entry⁵⁹, and one author investigated the influence of a prior medical degree⁵⁴. One author introduced a multiple choice exam as part of their selection process, which was based on subjects taught at high school level³¹. A review of subject choice at either high school or previous degree level was carried out by three authors^{29,55,64}.

Lala reported a moderate correlation between high school GPA and exam results in first year of dental school⁵ (Semester 1 $r=0.437$, semester 2 $r=0.313$). Arnold⁵⁵ found a weak but significant correlation between high school GPA and knowledge based assessments at year 1, half way and the end point of dental training. Lynch⁶⁰ reported a weak correlation between the Irish leaving

certificate results and performance in Year 1 assessments, but found no correlation with final year assessments. The remaining two authors found no correlation between previous degree results in a graduate entry school⁵⁹ or high school GPA⁶² and assessments throughout dental school.

In the four remaining studies in this category^{31,54,55,64}, significant findings were reported by Beier⁵⁴, Arnold⁵⁵ and Hoad-Reddick and Macfarlane⁶⁴. Having a prior medical degree had a small but significant effect on results in year 1 of the dental course, but this influence was lost at the point of a licensure exam⁵⁴. A review of high school subject choice showed weak but significant evidence of the positive effect of having studied school level Biology or Chemistry^{55,64}. The introduction of a high school level multiple choice exam (HAM-Nat) as a predictor of study performance by Kothe³¹ showed differing linear relations in each cohort, and in some cases they even exhibited an inverse direction.

4. Tests of psychomotor skills

Two authors investigated the use of a manual dexterity test^{55,57}. Arnold found weak correlation between the manual dexterity test and the practical component of the first dental examination taken at the midway point of dental studies ($r=0.20$)⁵⁵. Contrary to this, Giuliani reported that the use of a manual dexterity test at selection did not predict performance at a later date and that manual dexterity was something that could be taught⁵⁷.

5. Combination Tests

Seven papers reported on a selection process which included multiple tests^{30,33,35,56,61,63,67}. These selection processes used a variety of personal qualities^{30,35,56,61,63}, cognitive ability^{30,33,56,61,67}, knowledge^{33,35,56,63,67} and psychomotor skills^{30,33,61} to arrive at a total admission score which was then compared with performance at a later date.

Christersson³⁰ reported an 'Alternative admissions test' which consisted of tests of personal qualities, cognitive ability, academic attainment and psychomotor skills. Weak correlations were reported between small subsections of this test (Ravens advanced progressive matrices⁶⁹, Folding, Empathy, Interview) with subsections of the outcome measure used; student self-assessment and examiner assessment of diagnostic skills and interpersonal skills graded on a Likert scale.

Buyse and Lievens⁶⁷ reported the 'cognitive' portion of the Flemish admissions exam (FAE) which included 60 multiple choice questions (10 basic science [knowledge] and 50 cognitive ability). Weak correlations were reported between this and results in years 1-3 of dental studies (Year 1 $r=0.17$, Year 2 $r=0.12$, Year 3 $r=0.10$) but it was not found to predict results in years 4 or 5.

Buyse also reported the Flemish admissions exam (FAE) in a separate study⁵⁶. In this study the subsections of the test were not investigated separately and instead the total result of the cognitive (including knowledge), silent reading and situational judgement test was compared with students GPA in years 1-3. A weak but significant correlation was found between students FAE score and GPA in years 1 ($r=0.21$) and 2 ($r=0.14$) of dental studies but not year 3.

Beier³³ reported the Austrian Dental admissions test (ADAT), which includes cognitive and psychomotor components. This was shown to predict students results in first year of dental studies ($r=0.462$) and predict a student's ability to graduate on time ($p<0.05$).

Heintze reported the use of tests of general intelligence, spatial ability and manual dexterity (Cognitive and psychomotor). This included the use of Ravens advanced progressive matrices, tin models and folding, manual speed and accuracy and cavity reproduction. A moderate negative correlation was reported between two subsections of this test (Folding and Cavity reproduction) and course failure ($r = -0.32$, $r = -0.34$) and a weak negative correlation was found between two other subsections (Matrices $r = -0.23$ and Tin models $r = -0.29$). Two sub sections (Folding $r = 0.25$ and Tin models $r = 0.27$) also showed a weak correlation with scores in a preclinical course in operative dentistry. The test of manual speed and accuracy did not produce significant results.

The remaining two studies published by Roding et al.^{35,63} compared a selection process which included GPA, written tests (personal statement, motivation statement and an essay on either general knowledge, society or science), and an interview. This test was then compared with failure and drop-out rates throughout year 1 and 2 in one study³⁵ and 'professional competence', assessed by faculty on a Likert scale, in the other⁶³. Neither produced significant findings.

Research Design

A retrospective study design was favoured by most authors ($n=13$)^{5,28-31,33,54-56,58-60,67}. Most compared performance on selection with performance at various points throughout dental school. Seven authors reported to the end of 1st year^{5,28,31,34,58,63,64}, two to 2nd year^{35,65} and one to 3rd year⁵⁶. Of those reporting to final year^{30,33,54,55,57,60-63,67}, only six authors followed the full cohort through to completion of studies^{30,54,55,60,61,67} and three of these reported crude measurements of 'ability to graduate on time'³³, 'drop-out rate'⁶¹ and a Likert scale assessment of 'professional competence'⁶³. Only two studies reported on the outcome of a licensure or 'final' examination^{54,55}.

The majority of papers ($n=17$) reported single site studies^{5,28-31,33-35,54,55,57,59-61,63-65} and six of these 17 papers were single-cohort studies^{28,34,58,64,65}. The study population sizes ranged from 61³⁴ to 796³² (median= 122). No study reported a sample size calculation. There was duplication of study populations found across several of the papers by the same authors (i.e., the same study populations were reported twice^{29,33,35,54,56,59,63-65,67}).

Discussion

One of the most significant findings of this research is the notable dearth of published research examining dental schools selection processes across Europe. There are 228 dental schools in Europe⁷⁰ yet only fourteen have published any research in relation to admissions over the last 30 years. This is surprising, particularly when compared to a recent review of selection methods in medical education, which was carried out over a smaller time frame of 18 years and generated a much larger number of articles (194)³⁷. A vast array of data presumably exists in relation to dental schools admissions processes, and, no doubt, countless examples of good practice occur. However without sharing this information with wider audiences and publishing good quality research, we do not know if the admission processes used to gain entry to dental school are fit for purpose.

Although the current review was limited in relation to the points made above, some key findings did emerge which should inform future practice.

(1) Tests of non-academic attributes

The importance of these skills in dentistry is highlighted by their inclusion in the set of competencies required for dentists practising in the European Union⁷¹. Typically this has been assessed by interview^{30,34,35,58,61–65}, a format known to have poor reliability and validity in student selection^{72–74}. The evidence presented here confirms this by failing to reach any meaningful conclusion. There is some evidence that students admitted through interview are less likely to drop-out of dental school^{30,33,35,61}, but given the low drop-out rates in dentistry as a whole this argument has limited merit.

The onus is on dental schools to identify and adopt more robust methods for assessing non-academic attributes. The evidence from medicine suggests that SJTs^{75–80} and MMIs^{36,81,82} are worth investigating. This evidence supports the use of MMIs and SJTs in predicting performance, particularly as students' progress into the clinical years^{29,59,67}.

(2) Tests of cognitive ability

Only two countries reported the use of cognitive tests for dentistry in Europe, the UK^{5,34,59} and Sweden^{30,61} and consensus was not reached in relation to the predictive validity of the tools under investigation. Although the UKCAT is widely used by dental schools in the UK⁸³, there is a paucity of research examining the predictive validity of this tool in dental education. Research in medical education has shown that the UKCAT is a predictor of outcomes at medical school^{84,85}. Given the widespread use of this tool in the UKCAT, there is a pressing need to examine the predictive validity of the UKCAT and dental outcomes.

(3) Prior academic attainment & knowledge based exams

Since the 1950s the validity of academic achievement in the selection of health care professionals has been questioned^{42,43,86,87}. The evidence presented here shows high school GPA/prior attainment can predict performance in year 1⁵ but beyond this it has little⁵⁵ or no correlation with future performance^{60,62}. There is a lack of research in dentistry identifying how prior attainment relates to performance beyond graduation.

Prior attainment is no longer discriminating between candidates as increasing numbers of medical (dental) school applicants have top grades^{37,88}. Moreover, an over-reliance on A-level results in the UK may create a distorted social intake to universities⁸⁹. Further research is required to gauge the extent to which this is a problem in dental selection and education.

Further testing of knowledge at admission does not add any value to that already provided through prior attainment³¹.

(4) Tests of psychomotor skills

Whilst the practice of dentistry requires the ability to complete fine detail work, it appears from the literature that current tests of manual dexterity only have a weak correlation with early years psychomotor skills testing⁵⁵ and that this skill can be taught⁵⁷. This is consistent with other literature in the USA and Canada which have shown no practical utility of predictors of psychomotor performance^{90–92}. As far back as the 1970s the practical component of the USA Dental Admissions

Test was removed following research by Graham⁹³ which showed perceptual ability tests to be more reliable. Current evidence therefore supports that tests of manual dexterity are not used as part of the dental selection process.

(5) Combination tests

The research published on differing combinations of tests fails to reach any meaningful conclusion. This is unsurprising given the multitude of different factors being assessed within each test³⁰. The problem with this 'scatter-gun' approach is that it becomes unclear which part of the test predicted the outcome, even where authors attempted to differentiate this within their results^{30,61}.

Methodological Weaknesses in the current research

Study design

One of the biggest weakness in the current literature are the weak study designs and the lack of long term follow up. Current research findings are limited to performance at dental school, and most to early years^{5,28,31,34,35,58,64,65}. There is limited value of investigating year one performance in a five year course and what will become a potential 40 year career. Moreover, it appeared that new approaches to selection were adopted without piloting or testing, with no knowledge of whether or not they were fair, reliable or valid. Many studies were small scale and/or single site. We propose that collaboration across multiple dental schools to pilot and assess the utility of different, well-evidenced selection methods, would address some of the issues related to small sample sizes.

Outcome Measures

'A persistent problem with selection research relates to the issue of what outcomes we are trying to predict by using various selection methods', Patterson et al.³⁷. This is true in the studies reported here. Most authors to date have focussed on the ability of selection methods to predict performance on a limited number of (mainly) knowledge based in-course assessments^{5,28,29,31,33-35,56,58-60,64,65,67}. This is often despite the selection method purporting to assess something other than the 'knowledge' of applicants^{5,28,29,33,35,55,56,58,59,64,65,67}. The problem of selection tests (predictor variable) not aligning with the outcome criteria (criterion variable) has been discussed widely in the medical literature^{47,94}.

Another issue raised by measuring against indicators of academic attainment rather than factors relating to the clinical practice of dentistry, is that we may simply be admitting those who perform well at academic assessments. Evidence from the wider medical literature suggests that academic attainment is a necessary but not sufficient requirement for becoming a competent clinician^{1,95-97}.

Theory driven research

Within the published research there was a distinct lack of reference to the psychological theory supporting the use of the selection method being introduced. There is a wealth of research in the wider work psychology field in relation to selection methods including many systematic reviews, some of which span 85 years⁹⁸⁻¹⁰¹. Despite this, dental schools are continuing to use methods with low predictive validity, such as personal statements, and ignoring those that are more valid. This problem is not unique to dentistry¹⁰² but does leave dental schools open to criticism and possible litigation from unsuccessful applicants. "Quick gains" should be achieved by drawing on the medical and wider literature, instead of attempting to 'reinvent the wheel'.

Distortion (artefacts)

Small sample sizes and the single site nature of most studies may produce sampling error within the current research. Every study used academic qualifications as an initial hurdle to qualification, which diminishes the pool of candidates. Additionally the follow-up was only completed on those students who were successful in their application. The results published are therefore likely to underestimate the actual validity of the selection method. Future research should include corrections for range restrictions to highlight more accurate, and likely increased size, validity coefficients.

Strengths and weaknesses of this study

To the best of our knowledge, this is the first formal review of the literature on dental education selection criteria in Europe to have focused on the predictive validity of selection tools. The published literature across three databases was included in this review, and the process of reviewing was strengthened by numerous checks by all three authors. We omitted studies which were not published in English language and did not include conference abstracts, letters or unpublished literature. Our findings may therefore be subject to publication bias and the under-reporting of negative findings. A potential weakness of this study is that we did not systematically search the worldwide literature to explore the predictive validity of selection methods used. Although there is merit in learning from our international colleagues, we felt that the other confounding factors involved in selection would not be transferable to a European audience.

Disclosure and Conflict of Interest

CC, FP and JC had no conflict of interest and nothing to disclose.

Conclusion

It is clear from the discussion above that there is insufficient evidence of high quality from which to draw any conclusions as to the best selection methods or combinations of methods to use in dental school selection. Without this, designing selection frameworks for dentistry which are appropriately weighted, reliable and valid will remain a challenge. There is a need to move away from single site, small sample, and short-term designs to multi-centre²⁶, longitudinal²⁷, international studies. By gathering and analysing high-quality, longitudinal data, meaningful conclusions will be applicable to an international audience.

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Table 1

Types of Validity, summary of Chapter 4 in Arnold & Randall 2016⁴⁷

Type	What it is	Variations	Advantages	Disadvantages
Criterion Related Validity	The strength of relationship between the predictor and the criterion This gives a validity coefficient	Predictive (follow-up) Collects predictor information then follows up candidates to collect criterion data	Follows candidates through from selection to in job performance	Length of time to complete Only successful candidates will be tested at outcome
		Concurrent (Criteria related) Predictor data are obtained from existing employees on whom criterion data are already available	The organisation is not required to collect predictor data from job applicants and the ignore this during selection No time delay between collection of predictor and criterion data No lengthy follow-up	Incomplete sample and probably biased Workers may provide a population that may be different to the population of applicants Current job holders have already been selected using existing company selection procedures and represent a pre-selected group of people who have been with the organisation for some time May test skills acquired whilst doing the job
		Incremental Validity How much does adding an additional tool increase the predictive power	Allows a cost/benefit analysis of using additional tools	Difficult to interpret analysis
Faith	Belief that a selection method is valid		User acceptability	Not based on evidence
Face	It 'looks' right		Candidate acceptability	Not based on evidence
Content	Established on a logical basis A predictor shows content validity when it covers a representative sample of the behaviour domain being measured		Logical approach Content appropriate to target role	No statistical basis
Construct	Identifies the psychological characteristics (or constructs) such as intelligence, emotional stability or manual dexterity that underlie successful performance of the task in question		Important facet of understanding what the instrument actually measures	Assessed by indirect means and usually validated by comparing with results of an already established measure

Table 2

Results

Author/ Year	Study Population *	Follow Up	Predictor	Outcome Measure	Significant Yes/No/Partial	p value	
McAndrew et al 2017	n= 117 Two single cohorts (Parallel study)	BDS 1	Semi structured Interview (Newcastle)	BDS 1 Assessments (4 exams)	□	N	
			MMI (Cardiff)	BDS1 Assessments (2 exams)	□	N	
Lambe et al 2016	n= 228 Single Cohort	BDS1	Interview	BDS 1 Assessments (3 exams)	□	N	
			UKCAT SJT component	BDS 1 Assessments (3 exams)	□	N	
			UKCAT & SJT	BDS 1 Assessments (3 exams)	□	Partial	Exam 1 p= <0.01 Exam 2 p= <0.05 Exam 3 = N
Foley & Hijazi 2015	n= 71 Four cohorts (Only one cohort to final year)	Final Year	Preadmission academic score (PAS)	Combined assessment scores year 1-4	□	N	
			UCAS		□	N	
			MMI		□	Y	p= 0.001
			UKCAT		□	Y	p= 0.019
			UKCAT percentile		□	Y	p= 0.001
Christersson et al 2015	n= 283 Six Cohorts	Final Year	Alternative admission group - Problem solving matrices - Spatial capacity test (folding & tin models) - Manual Dexterity - Empathy - Interview	Drop-out rate	□	Partial	Comparison with Grade Admission p= <0.001 Tin Models p= <0.05
				Study rate	□	Partial	Comparison with Grade Admission p= <0.001 Empathy p= <0.05
				Examinations failed	□	Partial	Matrices p= <0.01
				Clinical Examination (Examiners= E) (Students Self Assessment= S)	□	Partial	Matrices p= <0.001 Folding S= 0.19 p= <0.05 Empathy S= 0.07 p= < 0.001
				Diagnostic skills (Examiners= E) (Students Self Assessment= S)	□	Partial	Matrices S p= <0.01 Empathy E p= <0.05
				Interpersonal skills	□	Partial	Y Matrices S p= <0.05 Y Empathy E p= <0.01 Y Interview S p= <0.001
Kothe et al 2013	n= 91 Two cohorts	BDS 2	HAM-Nat Natural Sciences Test	Physics Exam	□	N	
				Chemistry Exam	□	N	
				Science Exam - Physics	□	Partial	Cohort 1 only p= <0.05
				Science Exam - Chemistry	□	N	
				Science Exam- Biology	□	Partial	Cohort 2 only p= <0.05
				Dental Exam- Anatomy	□	N	
				Dental Exam- Physiology	□	N	
				Dental Exam- Biochemistry	□	N	
				Dental Exam- Dental Prosthetics	□	N	
				Lala et al 2013	n= 135 2 Cohorts	BDS 1	UKCAT Including Subtest scores QR/ DA/ VR/ AR
Semester 2= Oral Cavity	□	Partial	DA only p= <0.05				
Foley & Hijazi 2013	n= 75 Four Cohorts (Only one cohort to final year)	Final Year	Previous academic subject	Combined assessment scores year 1-4	□	N	Descriptive statistics only
			MMI		□	Partial	Teamwork p= 0.024 Communication skills p= 0.035 Work Experience p= 0.001 Manual Dexterity p= 0.003
Beier et al 2012	n= 122 Six Cohorts	Final Year	Prior Medical Degree (PMD)	Austrian DAT	□	Y	p= 0.042*
				Clinical performance after 1st year	□	Y	p= 0.03*
				Outcome of Licensure examination	□	Partial	Prosthodontics p= 0.013 Oral & Maxillofacial Surgery p= 0.005
Arnold et al 2011	n=196	Final Year	High school GPA	Natural Dental Science Examination (NDS) (end of 1st year) First Dental Examination (DE) (After 2.5 years) State Board Examination (SBE) (After 5 years)	□	Y	ALL p <0.001
			High School Subject choice		□	Partial	Biology component of NDS only p=0.008
			Non-structured interview		□	Y	NDS p <0.001 DE p <0.026 SBE p <0.006
			Practical Test		□	Partial	Practical component of first dental exam p<0.05
Buyse and Lievens 2011	n= 796	Final Year	Cognitive exam (MCQ 10 questions basic science + cognitive test 50 MCQs)	GPA in the five years of dental studies	□	Partial	Year 1 p<0.01 Year 2 p<0.01 Year 3 p<0.05
			Silent reading test (Read Medical literature then answer MCQ)		□	N	
			SJT		□	Partial	Year 5 p<0.01
			Flemish Admission Exam -Cognitive exam -Silent reading test - SJT		□	Partial	Year 1 p<0.05 Year 2 p<0.05
Beier et al 2010	n= 97	Partial to final year	Austrian DAT Theoretical & Practical Components	Performance in BDS 1	□	Y	p<0.01
				Graduation on time	□	Y	p<0.05
Kay et al 2010	n= 62	BDS 1	Interview	GAMSAT Student progress at the end of 1st year	□	N	
Giuliani et al 2007	n= 433	Year 5	Basic Manual Dexterity Tests (BMD)	Admission to Dental School Repeat of same tests at 3 & 5 Years	□	N	
Lynch et al 2006	n= 95	Final Year	Leaving Certificate Examination Ireland	First Dental Exam -Anatomy, Biochemistry, Physiology	□	Y	p< 0.05
				Final Dental Exam - Restorative Dentistry, Dental Surgery, Oral Health and Development	□	N	
Heintze et al 2004	n= 51- 191	Final Year	Tests of general intelligence, spatial ability and manual dexterity	Number of courses failed (CF)	□	Partial	CF Matrices p<0.01, Folding p< 0.001, Cavity Reproduction p<0.01
			Empathy and Social Competence Interviews	Pre-clinical course in Operative Dentistry (POD)	□	N	POD Folding p<0.01, Tin Models p<0.01
			Interviews	Temporary break off of studies or repeating a term & drop-outs	□	Partial	CF p<0.05
Fenton et al 2001	n= 302 Dental students in 3, 4 & 5th year	Partial to final year	Interview (UMDS- GST)	The Adult Eysenck Personality Questionnaire Revised short-form (EPQ-R)	□	Partial	Male age 16-20 Psychoticism p<0.05 Female and Male age 21-30 Extraversion p<0.05 Female age 21-30 Neuroticism p<0.05
			School exam results (TDS- Dublin)		□	N	
Röding 2001	n= 128	Final Year	Individualised Selection Process (Written Tests, GPA and Interview)	Professional Competence as assessed by faculty on a 1-7 scale	□	N	Descriptive statistics only
Hoad-Reddick & Macfarlane 1999	n= 112	Year 1	Interview	Performance during year 1 of the dental course	□	Partial	High score for leadership less likely to fail semester 2 p<0.03
			Subject Choice at A level		□	Partial	Without Biology A level- more likely to fail semester 1 or 2 p<0.01 Without Chemistry A level- more likely to fail semester 2 p<0.02
Hoad-Reddick & Macfarlane 1999a	n=117	Year 2	Interview	Performance in Year 1 & 2 of dental school	□	Partial	Interview- high leadership score less likely to fail semester 2 p=0.03
Röding 1997	n= 169	Year 2	Grade admission 3 Written Assignments Interview	Drop-outs	□	N	Descriptive statistics only
				4 Exam results throughout Year 1 & 2	□		

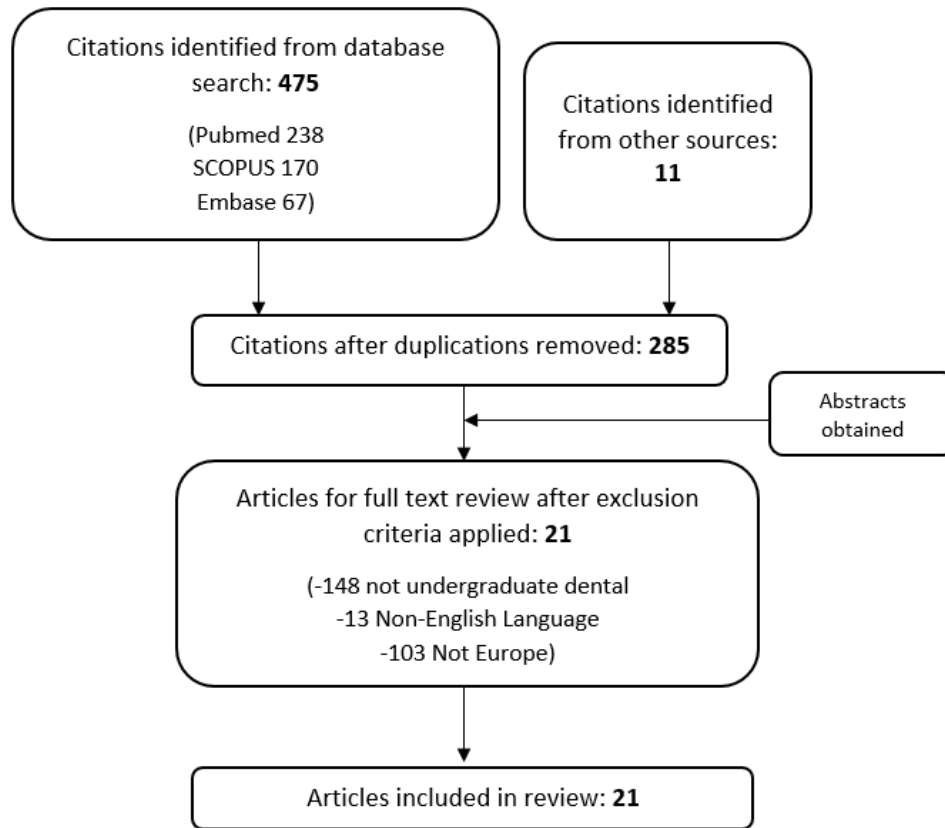
KEY	
Personal qualities/ non-academic attributes	◆
Cognitive ability	●
Academic attainment/ knowledge	□
Psychomotor skills	⌘

Table 3- Predictor versus outcome measure focus

Author/ Year	Predictor	Outcome Measure	Significant Yes/No/ Partial (Part of the predictor and/or part of the outcome)
McAndrew et al 2017	◆	□	N
Lambe et al 2016	◆ ●	□	Partial
Foley & Hijazi 2015	□ ◆ ●	□	Partial
Christersson et al 2015	◆ ● □ ⌘	□ ◆	Partial
Kothe et al 2013	□	□	Partial
Lala et al 2013	● □	□	Partial
Foley & Hijazi 2013	□ ◆	□	Partial
Beier et al 2012	□	□ ● ⌘	Partial
Arnold et al 2011	□ ◆ ⌘	□ ⌘	Partial
Buyse and Lievens 2011	□ ● ◆	□	Partial
Buyse et al 2010	□ ● ◆	□	Partial
Beier et al 2010	● □ ⌘	□	Y
Kay et al 2010	◆	● □	N
Giuliani et al 2007	⌘	⌘	N
Lynch et al 2006	□	□	Partial
Heintze et al 2004	● ◆ ⌘	□	Partial
Fenlon et al 2001	◆ □	◆	Partial
Röding 2001	□ ◆	◆	N
Hoad-Reddick & Macfarlane 1999	◆	□	Partial
Hoad-Reddick & Macfarlane 1999a	□ ◆	□	Partial
Röding 1997	□ ◆	□	N

KEY	
Personal qualities/ non-academic attributes	◆
Cognitive ability	●
Academic attainment/ knowledge	□
Psychomotor skills	⌘

Figure 1- Process of Investigation



Box 1 – Context of the study

The focus is on European studies for two reasons; analogous student populations and comparable workforces upon graduation. Within the EU the majority of dental schools are undergraduate courses, which students enter after completion of high school or equivalent. Although there have recently been the addition of some 'graduate-entry' dental schools in the UK, these differ only in their academic entry criteria when compared to undergraduate schools; university qualifications in specific science related degrees are considered to supersede school qualifications. Students attending graduate entry school are subject to the same funding, fees and learning outcomes and will enter the workplace in the same conditions as their undergraduate counterparts. The dental workforce across the EU is also similar. Dental graduates from European schools can choose to work within any area of the EU due to the current economic policy of free movement between member states. The majority of dental graduates work within privately owned dental practices, with a varying degree of government funding. The candidates applying to dental school throughout the EU should therefore be comparable.

On the other hand, non-EU student populations are subject to a vast array of confounding factors making useful comparisons potentially inconsequential. Factors such as vastly increased cost of study, country specific entrance exams and graduate entry student populations are prevalent in the rest of the world. For example, the average tuition fees in the US is estimated at up to \$46,859. When combined with additional costs of study, the average US graduate can expect to graduate with over \$200k worth of debt (ADEA 2010). A recent study of UK final year dental students estimated total debt at £24,734 (BDA 2014). Student debt is often cited as one of the main contributors to students choosing not to attend university, or failing to complete studies if they do attend (Guardian 2015). The USA also employs the use of an entrance exam into dental college, The Dental Admissions Test (DAT) which is exclusive for use in USA schools. No such universally-used test exists in the EU. Graduate entry schools are also prevalent in the rest of the world. Exclusively graduate-entry contexts, such as the USA, may also influence the nature of the applicant pool (e.g., Gallagher et al 2009).