Can Utilizing Business Intelligence with Electronic Dental Record Data Improve Business Decisions for Dental Organizations: A Scoping Review

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Abstract

Background Business intelligence can give businesses the ability to understand their strengths, weaknesses, and opportunities for improvement and can help reduce uncertainty in the decision-making process. With the increasing use of electronic dental records creating more and more dental data each day, it is an opportune time to determine if the data can be coupled with business intelligence systems to improve the management decision-making process in dental organizations to result in service improvement.

Methods A scoping review was performed to map the research on the use of business intelligence in dental organizations and to identify any gaps in the existing literature. This scoping review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-Scr) framework. The following databases were searched: Medline, Embase, Emcare, Cinahl, Informit, Web of Science, and Scopus. Data extracted from the articles included the organization type, purpose/aims, the software utilized, data sources utilized, outcomes measured, decision-makers involved, service benefit type, and service improvements.

Results In all, 945 articles were found during the search strategy, with 25 articles selected for full-text review. Of these 25 articles, only 3 met the final inclusion in this review. All three included articles were centered around dental school organizations and all situated in the United States. All three articles demonstrated a benefit from management decision-makers utilizing business intelligence systems for improving service efficiency.

Conclusion There is limited evidence to show that managers utilizing business intelligence systems in dental school organizations can lead to improvements in the organization's services. There was no evidence to support the use of a business intelligence system in other types of dental organizations. More research is required in this area.

Keywords
► business intelligence
► data mining
► electronic health records dentistry
► oral health

Introduction

"Business Intelligence" is defined as "*technologies, applications and practices for the collection, integration, analysis, and presentation of business information. The purpose of Business Intelligence is to support better business decision-making. Essentially, Business Intelligence systems are data-driven Decision Support Systems*."[1] Business intelligence can give businesses the ability to understand their strengths, weaknesses, and opportunities for improvement. Business intelligence systems are designed to reduce uncertainty in the decision-making process and help improve managerial practices by providing additional insight into the business's historic data and trends. These systems are comprised of multiple parts: a data source such as a database, a set of data analytics tools, and a frontend of the system enabling the user to investigate the data.[2] An example of a data source that could be used with business intelligence is a database containing clinical data from dental electronic records.

Electronic dental records are perceived to provide some benefits over paper dental records. These include increased legibility of notes, improved patient care, and improved efficiency for dental staff.[3] The use of electronic dental records for clinical documentation has been mentioned in the literature as far back as the 1980s.[4] The Dental Board of Australia states that dental records must contain, but are not limited to, the patient's identifying detail, medical history, clinical findings, treatment plans, treatment history, and diagnostic imaging.[5] The data contained within electronic dental records are typically stored in a database, which allows for quick retrieval of large amounts of data compared with data contained in paper records that have to be read individually.[6]

Adoption rates, in the United States, are reported to be between 78 and 85% in recent studies, increasing from just 11% in 1984.[3] However, analysis of these data contained in electronic dental records has been limited and is likely due to the slow adoption of electronic dental records until now, nonstandardized clinical dental records, limited data access between dental organizations, and limited integration between general health and dental electronic records.[7]

Dental organizations can include a varying degree of organizational types, and in Australia, this includes public organizations such as the public health system, correctional facilities, defense facilities; private organizations; and tertiary education organizations such as universities and not-for-profit organizations such as the Aboriginal Health Service.[8] Managers of dental organizations including clinical managers, business operations managers, and policymakers are often required to make decisions for their organizations, which can include financial, operational, or clinical decisions. Often there are multiple choices the manager can choose from and it is expected that the chosen option would provide the best clinical, financial, or operational outcome depending on the decision. An ideal decision-making process would involve a detailed analysis of each option.[9] To facilitate this, immediate on-hand data such as the data provided by a business intelligence system could be beneficial.

Other areas of health care have shown benefits when health care managers utilize business intelligence systems, including improved service quality,[10,11] improved patient outcomes,[12,13] improved risk assessments and management,[14,15] and improved service efficiencies.[16,17] It is expected that these benefits could also be achieved in dental organizations if dental managers utilized a business intelligence system during their decision-making requirements.

Aim

With the increasing use of electronic dental records creating more and more dental data each day, it is an opportune time to determine if these data can be coupled with business intelligence systems to improve the management decision-making process in dental organizations. This study aims to determine if there have been any previous experiences published in the literature of applying business intelligence systems with electronic dental record data to improve the decision-making processes in the management of dental organizations with an expectation that improved decision-making will result in dental service improvement.

Methods

A scoping review was performed to map the research completed in this area and to identify any gaps in the existing literature. This scoping review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-Scr) framework.[18] For an article to meet the inclusion criteria in this review, the article was required to report the utilization of a business intelligence system of any type (including preexisting business intelligence systems or business intelligence systems created in-house), the article was required to be related to dental/oral health, and at least one source of data must have been from data contained within electronic dental records. For this review, electronic dental records include any electronic dental record software that may contain either complete dental records or partial dental records as long as the required information was stored electronically. Other criteria required included the following: the article must have been published in the past 15 years (2005–2020) which correlates closely with the emergence of business intelligence systems[2] and all article types were allowed into this scoping review.

To find all relevant articles, the following databases were searched: Medline, Embase, EmCare, CINAHL, InformIT, Web of Science, and Scopus. These databases were selected due to their focus on medicine, allied health, and health care including dental/oral health. If the searched database included gray literature, this was included in the initial search.

The initial search strategy was created by the first author and was reviewed by the Research Librarian from the University of Newcastle. A further review was then performed by the remaining authors. The final search strategy is

detailed in ►**Fig. 1**, and included business intelligence and the subset function terms of business intelligence such as data analysis. These broad terms were used to try and capture all related articles in the initial search. The results of the search were exported into the Endnote software and duplicates were removed within the software. The screening process was performed by the first author and then reviewed by the remaining authors. Any disagreements during this process were resolved after discussion and by a consensus process.

Data extraction on the included studies was conducted by the first author and reviewed by all other authors. The extracted data from the articles included the first author's last name, the article's year of initial publication, country of origin, organization type, purpose/aims, the software utilized, data sources utilized, outcomes measured, decision-makers involved, service benefit type, and service improvements.

Results

A total of 945 articles were found during the search strategy, and 499 were duplicates. After reviewing the titles and abstracts of the remaining articles, 25 articles were selected for full-text review. Of these 25 articles, only 3 met the final inclusion criteria in this review. A PRISMA flow diagram is detailed in ►**Fig. 2**. A summary of the three included articles can be found in ►**Table 1**. All three included articles were centered around dental school organizations and all situated in the United States. Two of the articles were from the same dental school and utilized the same electronic dental record software, while the third article centered around their custom "Faculty Request System" software utilized by the dental students performing clinical duties, which linked with appointment data from their existing software.

The findings of Filker et al suggest that the organization can use the data reported in the article to assist in the planning of future dental clinic outreach locations. This, in turn, would improve dental access for patients with higher oral health care needs. The findings also suggest that the organization is not maximizing the impact the service could have in surrounding high-caries-risk areas. The conclusion from this article states that the data present in electronic dental records present multiple opportunities for future program planning and research.[6]

Alternatively, the article by Nalliah et al focuses on improvements in their existing clinics by analyzing the
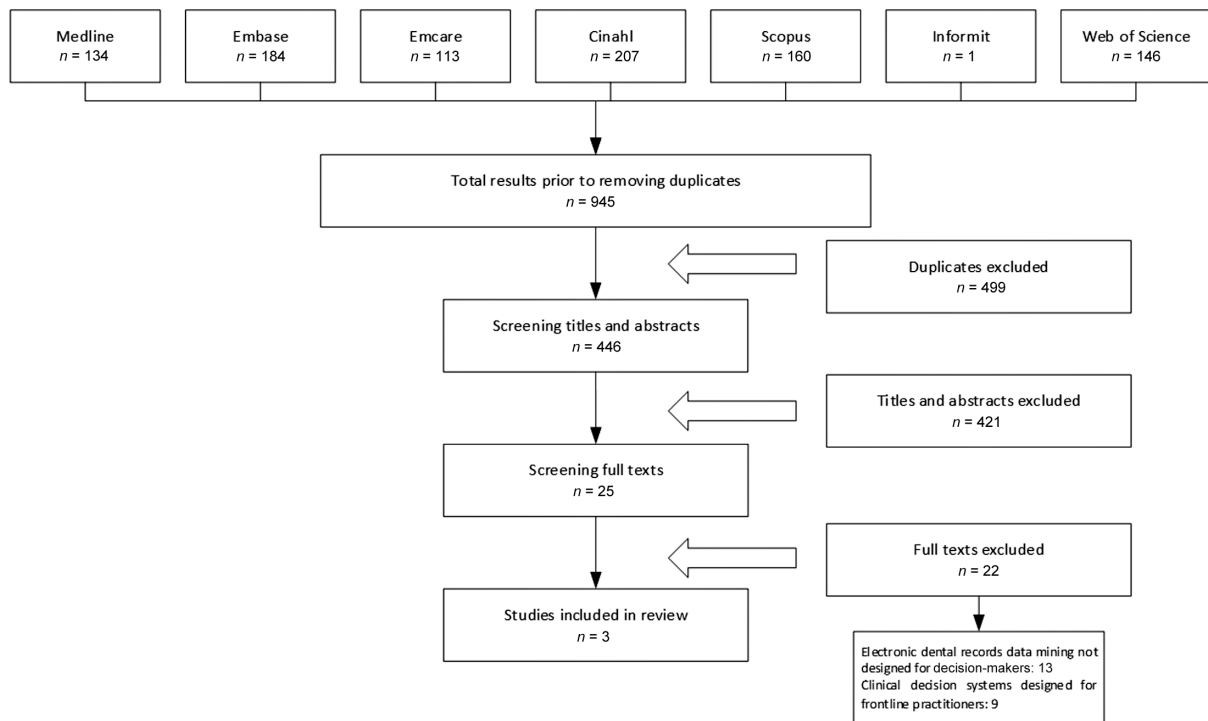

Fig. 2 Preferred Reporting Items for Systematic reviews and Meta-Analyses (Prisma) flowchart of phases in this scoping review.

Table 1 Summary of included articles

Study	Country	Organization type	Article purpose/aim(s)	Business intelligence software utilized	Data source(s)
Filker et al[22]	United States	Dental school	"…to describe the quality assurance system at NSU-CDM and explore the impact the introduction of electronic health records has had"	• AxiUm: electronic dental record software • Crystal reports: reporting software	• Electronic dental record
Filker et al[7]	United States	Dental school	"…to determine if there was a relationship between high oral health care needs and patient demographics, including gender, age, and the median income of the zip code where they reside to support dental school strategic planning including the locations of future satellite clinics"	• AxiUm: electronic dental record software • Infomanager: reporting software within AxiUm • MapInfo: mapping software • IBM SPSS: statistics software	• Electronic dental record • Geographical information database
Nalliah et al[21]	United States	Dental school	"…to assess the effects of this change, including the quality/process improvement interventions that were possible due to information revealed by the FRS"	• Facult Request System • Tableau: business intelligence tool	• Faculty Request System • Electronic dental record (appointment data only)

Study	Outcome(s) measured		Service benefit type		Service improvement(s)
Filker et al[22]	Track outcomes of procedures performed in its clinics to assist with quality assurance		Service quality improvement		It was determined through data mining and reporting of electronic dental record data that some clinical educators were using non-evidence-based treatment materials for pulp capping. Further education was provided to these clinical educators to improve treatment outcomes for patients
Filker et al[7]	• Number of dental patients seen categorized by patient demographics • Caries risk status • Patient's residence by zip code median income • Clinic locations by zip code median income		Service efficiency improvement		Patient data within the electronic dental records were combined with geographical data to help assist where possible future outreach clinics should be placed to maximize dental access for patients with high dental needs
Nalliah et al[21]	• A dental student's time spent away from patients waiting for a clinical supervisor • Appointment start/end times and appointment lengths • Treatment time • Appointment utilization		Service efficiency improvement		Analysis and reporting from the Faculty Request System combined with patient appointment data provided the organization with various trends related to student–patient interaction time and appointment metrics. Some negative trends were determined and the organization was able to put controls in place resulting in less time for the students being away from their patients and better utilization of appointment time

data recorded from their Faculty Request System. The analysis of the data determines that the amount of time a student dental practitioner spent away from their patient awaiting a clinical supervisor decreased from an average of 40.6 to 12.1 minutes, a 70.2% reduction, after the implementation of the Faculty Request System. While this outcome was the primary aim of this article, analysis and reporting of the Faculty Request System data also determined multiple negative trends the organization was previously unaware of, and the organization was able to improve these trends once discovered. After an investigation into the number of supervisor requests per student, it was determined that a lot of the high number of requests were from inefficiencies with the student using the electronic record during examination appointments and requesting a supervisor for each step of the examination documentation process. The organization was able to decrease the number of requests by the students for the examination appointments by creating a checklist for the students detailing when to request a supervisor. This then decreased the requests from a mean of 5.14 to 3.83 resulting in a further decrease in time students spent away from their patients. Other negative trends the business intelligence data demonstrated were a decrease in treatment/patient bookings toward the end of the week and a mode delayed start time of 15 minutes. The organization was able to put controls in place to improve both of these trends.[19]

The last included article by Filker et al had an aim to describe a quality assurance system and the impact of the introduction of an electronic dental record system on the dental school organization. While the aim of this article was not relevant to this scoping review, the authors discuss plans for the organization and determine that the data and reports from the electronic dental record can be used to determine unacceptable treatments and investigate reasons for poor patient outcomes. An example in the article where the organization had already addressed a poor outcome was related to staff members that continued to promote calcium hydroxide for pulp capping. This was not in accordance with the dental school's evidence-based standards and protocols that were in favor of other materials to be used. The staff members in question were able to be provided with additional education to help them transition to current evidence-based practices that will lead to better treatment outcomes for patients.[20]

All three included articles that were accepted into this scoping review demonstrated that utilizing business intelligence at an organization level can aid decision-makers in improving their dental school organization's services. There was no evidence to support the use of a business intelligence system in other types of dental organizations.

Discussion

This scoping review only resulted in three articles being included. The limited articles were able to show that

business intelligence through data analysis and reporting back to decision-making managers of dental school organizations can aid these decisions that in turn will lead to improvements in the organization's services for clinical services, service planning, and student–patient interaction. Of the included articles in this scoping review, all three articles were related to dental school organizations. No articles were found for business intelligence systems applied to public or private dental organizations resulting in no evidence that business intelligence system utilization has a benefit in other dental organization types. It may be possible that the positive outcomes detailed in the included articles in this review would apply to other dental organization types outside of tertiary teaching. However, further research would be needed in this area. It may also be possible that other dental organization types have determined that the effort and cost of implementing a business intelligence system in their dental organization outweigh the benefit and thus not published literature in this area. It may also be possible that other dental organization types have already implemented a business intelligence system but have not published their findings due to intellectual property restrictions or not providing trade secrets to their competitors.

This scoping review has demonstrated that there is very little literature on business intelligence use in the dental setting, particularly in comparison to the medical setting where business intelligence has a larger volume of evidence in the literature.[10,13,21]

Of the remaining 22 full-text articles that were reviewed but not included in this scoping review, they all fell into two groups: clinical decision systems and electronic dental record data mining. Clinical decision systems are designed for frontline practitioners and help them in their clinical decision-making with patients. However, as these systems are designed for the frontline practitioner and as this study is focused on the decision-making of dental organization managers, these articles were not of any interest in this review. The studies where data mining had occurred on electronic record databases with examples of these including determining patient's smoking status,[22,23] the longevity of restoration materials using the retrospective data contained in electronic dental record databases,[24,25] population data of dental patients[26] and dental disease prevalence and correlations for various patient factors and dental diseases[27,28] could be of interest in future research. Although the data collected in these studies were not presented via a business intelligence system or did not indicate how the data could be utilized by decision-makers at a dental organization to improve outcomes, the data theoretically could be utilized within a business intelligence system to provide up-to-date information to decision-makers allowing them to make evidence-based decisions on their own population/patient data.

The limited number of included articles indicates a gap in the literature and prohibits any strong conclusions about the

effect of business intelligence utilized by decision-makers in dental organizations.

In conclusion, there is limited evidence detailing outcomes from decision-makers of dental organizations utilizing business intelligence systems, despite successes seen in the medical field. The limited evidence indicates that these systems do have a benefit when utilized by managers of dental school organizations when performing decision-making. However, more research is required in this area, particularly with other types of dental organizations. The studies included in this scoping review only focused on service efficiency improvements. Research into other areas such as determining if the use of a business intelligence system could benefit dental organization managers with their decision-making in improving service quality, improving patient outcomes, and improving risk management would help address this research gap. The authors recommend that researchers and managers of dental organizations perform collaborative research to determine the requirements of management decision-making of dental organizations utilizing their own organization's data from electronic dental records and encourage researchers to publish in this area at the same time.

Clinical Relevance Statement

Business intelligence systems have demonstrated that they can aid management decision-making in health care, which can result in improved service quality,[10,11] improved patient outcomes,[12,13] improved risk assessments and management,[14,15] and improved service efficiencies; however, there is not enough evidence to confirm that these benefits of business intelligence systems also apply to dental organizations. Additional research is required to confirm that business intelligence systems can aid management decision-making of dental organizations.

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