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Need for a diagnostic centric care in dentistry: a case study from Marshfield Clinic Health System

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Abstract

Background—The study objective was to evaluate the workflow of dental providers who use the existing Electronic Dental Record (EDR) system at a large, regional health care system, to establish a diagnostic-centric culture as part of their dental practice. A further goal focused on identifying where improvements to the workflow and design of the EDR may be indicated.

Methods—Dental procedures performed on patients and corresponding International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) diagnoses were retrospectively mined from Marshfield Clinic's enterprise data warehouse. All dental procedures performed were selected and paired with corresponding diagnostic codes documented by dental providers. Frequency of documented diagnosis was further analyzed by characterizing correspondence with their ranking order in the diagnoses column with/without scrollbar within the EDR user interface (UI). Accuracy of selecting appropriate ICD9-CM for the corresponding Code on Dental Procedure and Nomenclature (CDT) was checked for 10% (6,187) of the procedure-diagnosis pairs.

Results—Of the 61,511 unique procedures documented using 147 CDTs, 11% (6,914 procedures) had a corresponding 'not available' option associated under the diagnoses column, while 89% (54,597) of dental procedures were associated with a corresponding ICD-9-CM diagnostic code. Overall tendency of dental providers to select the first or last options from the

diagnostic list with a scrollbar was noted. Appropriateness of documenting corresponding ICD-9-CM to CDT procedures showed 98% accuracy.

Conclusion—EDR UI design impacted greatly on documentation process. Redesigning the EDR UI based on the results will increase both the quality and utility of clinical documentation.

Keywords

Code on Dental Procedure and Nomenclature (CDT); Electronic Dental Record (EDR); Electronic Health Record (EHR); International Classification of Disease (ICD); Structured Data Documentation; User Computer Interface

INTRODUCTION

Code on Dental Procedure and Nomenclature (CDT) has been integral to dentistry for several years as a standard lexicon of procedural codes used to report dental services as defined by the American Dental Association (ADA).¹ Developed by the ADA, CDTs support efficient processing of dental claims and capture of dental procedural history in the electronic dental record (EDR).¹ An accurate recording of a treatment plan in an EDR requires not only the procedure that is planned, but also the associated diagnosis, as it is essential to capture the reason for the procedure being performed. Recently, the Health Information Technology for Economic and Clinical Health (HITECH) Act² and the emergence of multiple dental diagnostic vocabularies have placed additional emphasis on need for capturing diagnoses in the EDR.^{3–6}

In recent years, the growing recognition of integrating dental and medical electronic health records is considered a significant opportunity to not only improve patient care and support quality of care initiatives, but also to reduce the informational silos that exist between these two domains.^{7,8} However, this exchange of information through the delivery of care process in an electronic health record (EHR) is still identified as a barrier due to lack of standardization. Moreover, there is a different range of workflows associated with medical and dental documentation for treatment planning.⁷

The advent of different dental diagnostic vocabularies has highlighted that currently there is no mandated, standardized, dental diagnostic terminology for the field of dentistry. International Classification of Diseases, Tenth Edition, Clinical Modification (ICD-10-CM) codes are currently being utilized as a cornerstone and back end reference terminology for reporting standard completed treatment transactions for diagnosis, disease, and other health problems in medicine, which recently transitioned from ICD-9-CM to ICD-10-CM in the United States. Backend reference terminology is defined as, “a terminology where each term has a codable, computer usable definition to support retrieval and data aggregation.”⁹ Although ICD terminology is not as robust as the dental concepts detailed in SNOMED International (formerly known as the Systematized Nomenclature of Medicine (SNOMED) and, although ICD-10 has greatly improved the level of granularity over ICD-9, ICD-10 still lacks the granularity needed to document detailed dental problems and findings. Efforts to create standardized dental diagnostic terminologies have resulted in: Systematized Nomenclature of Dentistry (SNODENT),¹⁰ developed by the ADA, as well as EZCodes, a

standardized controlled terminology for dental diagnosis that was developed by a diagnostic terminology research work group and catalyzed by the Consortium for Oral Health Research and Informatics (COHRI).³ SNODENT falls under the auspices of SNOMED International (formerly known as the International Health Terminology Standards Development Organization (IHTSDO)). The Dental Diagnostic System (DDS), formerly known as EZCodes was developed as an interface terminology. Accordingly, the interface terminology was defined as a group of terms that are designed in a manner that adapts to the user's natural language and is easily mediated through the concept descriptions and underlying reference terminologies.⁹ More recently, SNODENT (terminology subsets of SNOMED International concepts), was accredited as an American National Standard Institute (ANSI)-certified standard and supports sharing a structured dental diagnosis within HL7 Clinical Document templates such as Continuity of Care Document.^{10,11} A recent harmonization effort between SNODENT and DDS resulted in two SNODENT subsets, SNO-DDS and SNO-DDS General Dentistry (a subset developed for general dentistry).¹² These codes are organized into subcategories and major headings using the best terminology development practices.

The majority of current EDRs now have the functionality to store data in a structured format.¹³ The User Interface (UI) design of an EDR plays an important role in supporting documentation of structured information while keeping the contextual relevance between the procedures performed and the clinical indication for which the specific procedure was performed. Historical usability studies have focused on issues faced by clinicians in completing routine tasks, barriers to adopting EHRs, and clinicians' abilities to document or view clinical data efficiently.^{11–14} Other studies have also explored the UI designs of EDRs.^{15–17} A recent study that evaluated UI-related problems involved with structured data entry encountered by dental providers identified 24 high level usability problems.¹⁶ Unexpected approaches for displaying diagnoses, lack of visibility, and inconsistent use of the UI widgets were some of the high level usability problems reported in the study.

The objective of this study was to evaluate and report on the workflow of dental providers who use the existing EDR system at a large, regional health care system to establish a diagnostic-centric culture as part of their dental practice. A further goal was also to identify where improvements to the workflow and design of the EDR may be indicated.

METHODS

Description of care setting

Founded in 1916, Marshfield Clinic is one of the largest comprehensive medical-dental health systems in the United States.¹⁴ This 700+ physician, 40+ dentist, 7600+ employee, multispecialty group practice provides patient care, research, and medical education across 57 locations throughout its service area spanning central and northern Wisconsin. Family Health Center of Marshfield, Inc. (FHC), a member of Marshfield Clinic Health System (MCHS) and a Federally Qualified Health Center (FQHC), has been serving low-income, underinsured, and uninsured individuals since March 1974. FHC has partnered with Marshfield Clinic in operationalizing onsite dental services since the fall of 2002 via ten

regional dental clinics integrated into MCHS and provided care to >50,000 unique patients annually in central, western, and northern Wisconsin.

Description of the EDR environment

MCHS has made a significant commitment to the internal development of its clinical information systems over the last 40 years.¹⁵ As part of this effort, MCHS has developed a robust integrated medical-dental electronic health record (iEHR) environment.¹⁴ In 2010, a mandated modification to the EDR module of the iEHR included redesigning of the documentation practice at the health system's dental centers. This modification supported diagnosis selection by dental providers to the corresponding procedure. Thus, as a requirement for proceeding with treatment planning, the provider must select a diagnosis to move forward with the treatment planning. Because ICD-9-CM dental diagnostic code sets were most commonly available at that time, a decision was made to implement those within the EDR. Figure 1 illustrates the redesigned UI of the EDR, which supported the documentation of procedures and associated diagnoses.

When the provider selects a specific procedure, a corresponding list of potential ICD9 dental diagnoses is displayed in the diagnoses column. The treatment plan is generated in the progress notes once the provider has selected a corresponding diagnosis and the 'TxPlan' button is clicked. To denote a lack of appropriate dental diagnosis among available ICD-9-CM codes in the diagnoses column, a 'none' option was included in the list. For the purpose of this study, all other dental specific ICD-9-CM codes were considered 'available' diagnoses, the appropriateness of which was determined by the dental providers when they documented the information in the EDR. The 'none' option indicated lack of an appropriate diagnosis among current potential ICD-9-CM options. In certain instances, CDT codes were not required to be associated with diagnostic codes. For example, the information under the diagnoses column for CDTs in the context of panoramic radiographs, maxillofacial prosthesis, and orthodontic category of services were left blank by default, allowing the provider to proceed directly to treatment planning. Thus, lack of availability of a diagnoses due to 'default' was distinguished from the 'none' option, where candidate diagnoses were available but not deemed appropriate by the provider. Finally, providers had the option of manually entering a diagnostic code in instances when they did not deem candidate diagnostic codes presented to be appropriate, but did identify an appropriate diagnostic code that was not presented as an option. In the present study, 'default' diagnoses (that were essentially blank) and manually entered diagnostic code were excluded from the analyses. Additionally, oral and maxillofacial surgeries are usually performed in medical centers that use the medical component of the integrated electronic health records (that has a different user interface) for documentation. Therefore, as it has a different user interface, this category of service was also excluded from analyses in the present study. However, all data (including default option and the excluded category of services) were used to check the appropriateness of the documented procedure-diagnosis pairs (CDT-ICD pairs).

The EDR UI design varied for the diagnoses column depending on the number of candidate diagnostic data elements associated with a selected CDT. Figure 2 illustrates the two different EDR UI designs, one with a scrollbar (accommodating about 16–23 unique ICD-9-

CM codes) and one without a scrollbar (accommodating about 16 ICD-9-CM codes) under the diagnoses column based on the length of the candidate diagnostic list. This modification to EDR documentation practice at the dental centers provided the opportunity for the study team to focus on the dental treatment plan workflow and EDR documentation practices and inform on any further refinement of EDR design to facilitate accurate data entry by the providers during dental care delivery in clinical settings. The study was reviewed and approved by the Marshfield Clinic Research Foundation Institutional Review Board using expedited review.

Data collection

To achieve the objective of the study, retrospective data surrounding treatment planning workflow were mined from MCHS's enterprise data warehouse (EDW) inclusive of the 4-year temporal window coinciding with the mandate for diagnosis documentation in the EDR from its introduction in 2010 through 2014. The study data set included capture of the patient's medical history number, gender, age, ethnicity, date and dental center visited, CDT used for documenting dental procedures performed on the patient, and the corresponding ICD-9-CM dental diagnosis documented by the dental provider.

Retrospective data analysis

Abstracted data were sorted according to the nine CDT categories of services consisting of diagnostic, preventive, restorative, endodontics, periodontics, prosthodontics removable, implant services, prosthodontics fixed, and adjunctive services. To understand the use of CDTs, the total number of dental procedures and the total number of unique CDT codes used under each category of service were evaluated. The corresponding number of actual available ICD-9-CM codes in the diagnoses column entered by the providers and selection of 'none' indicating perception that appropriate diagnostic code was 'not available' were also evaluated. Additionally, 10% of the CDT codes with and without ICD9 codes under each category of services were manually reviewed for accuracy and appropriateness of coding. A trained dentist from the research team conducted EHR chart audit and confirmed appropriateness of the procedure–diagnosis pairs for about 10% of all categories of services (COS) by retrieving the clinical notes for the corresponding CDT procedures performed. Statistical analyses including two sample proportion tests were performed on the retrospective data evaluated based on COS, CDTs, and ICD-9-CM codes. Histograms were derived following application of descriptive statistics, and results were reported as counts and/or percentages.

User interface analysis

To evaluate the impact of UI under the diagnoses in columns with and without scroll bars (as shown in Figure 2) on workflow patterns of selections of diagnoses by dental providers based on their rank ordering within the diagnoses column were analyzed within the context of the corresponding CDTs. Additionally, the frequency and validity of selection of the first and last diagnostic code option in the diagnoses column for each service category was compared to frequency of selection of other available codes ordered between these two options. This analysis was undertaken to assess whether rank ordering at those positions may have disproportionately influenced selection of the first or last diagnostic code options

irrespective of accuracy. Since the last ranked position was ‘appropriate diagnosis not available’, accuracy of this selection was ascertained by examining clinical procedural notes and claim notes to see if these provided the basis for selection of an available diagnostic code from among the candidate list of diagnoses or determine a need for inclusion of additional codes, if available. The study was reviewed and approved by using expedited review by the Institutional Review Board of Marshfield Clinic Research Foundation.

RESULTS

During the defined 4-year study window, treatment plan documentation was performed by 83 actively practicing dental providers (dentists and dental hygienists). Marshfield Clinic’s EDW query identified 43,943 unique patients that visited the dental centers during the 4-year timeframe between 2010 and 2014, whose data were available for inclusion in the study. Of these, 57% (25,160) were females, and 43% (18,987) were males. The average age of females was 41 years and that of males was 42 years. The majority (>90%) of this patient population was Caucasian and non-Hispanic/Latino, and representative of the population within the service area of the MCHS dental centers. Overall, performance of 61,511 unique dental procedures was documented during the study period, with corresponding ‘available’ diagnosis and, ‘not available’ option captured in the EDR. Table 1 shows the distribution of the total number of dental procedures across the nine CDT categories of service and the corresponding numbers and percentages of documented ‘available’ and ‘not available’ diagnosis, unique CDT, and unique ICD-9-CM codes.

Among 185 unique CDTs available under the nine categories of services in the EDR UI to document the dental procedures from, about 2% (n=38) of unique CDTs were never used by the dental providers during the study period, indicating that those procedures were never performed. Of the total dental procedures, 11% (6,914) had a corresponding ‘not available’ option associated under the diagnoses column, reflecting the lack of appropriate dental diagnosis available under the diagnoses list for the corresponding dental procedure (providers selected the ‘none’ option from the diagnoses list), while 89% (54,611) of dental procedures had a specific corresponding ‘available’ diagnosis, reflecting the availability of a specific ICD-9-CM dental diagnostic code to choose from the diagnoses list.

For the 54,597 procedures documented that had a specific corresponding ‘available’ diagnosis, 101 unique ICD-9-CM codes were used. Of these 101 ICD-9-CM codes, the most frequently documented diagnostic codes as a reason to perform a specific dental procedures were: *V72.2- dental examination* [(46.3%) 25278/54597], *338.1-acute pain* [(26.8%) 14641/54597], *521.00- unspecified dental caries* [(7.3%) 3983/54597], *338.2-chronic pain* [(4.9%) 2684/54597], *521.02-dental caries extending to dentin* [(2.6%) 1397/54597], *525.64-fractured dental restorative material with loss of material* [(1.3%) 669/54597], *523.4-chronic periodontitis* [(1.2%) 647/54597], *525.63-fractured dental restorative material without loss of material* [(1.0%) 566/54597]. The remaining 67[(8.7%) 4732/54597] ICD-9 CM codes were very seldom documented.

When a unique CDT that the provider wanted to document in the EDR was associated with a lengthy candidate diagnoses column, the dental provider was required to use a scroll bar to

review and select the most appropriate corresponding diagnosis for the procedure being performed. Of the 185 CDTs, 83 CDTs (45%), which represented 52,701 dental procedures, had a corresponding EDR UI with a scrollbar to present the list of diagnoses, while 59 CDTs (32%) which represented 8,810 dental procedures had an EDR UI without a scrollbar. The 'not available' option was consistently positioned as the last term when candidate diagnostic lists for the corresponding CDTs were made available. Figure 2 illustrates the two different EDR UI designs reported above. The 'not available' option was selected 12% (6,310/52,741) of the time from the diagnosis column for EDR UI with a scrollbar, while it was selected 15% (1,323/8,820) of the time without a scrollbar.

The results of the evaluation of the accuracy of the procedures-diagnosis pairing that was done manually are shown in Table 2. Eight ICD-9-CM codes that were used to document two diagnostic, two fixed prosthodontics, and three restorative COS respectively, could have used more granular ICD-9-CM codes. Similarly, 13 removable prosthodontic COS and one preventive COS did not have any ICD-9-CM code to describe the specific procedures such as denture wax try-in, denture primary impression, denture final impressions, and restoration of sedative filling.

DISCUSSION

Our study explored the documentation of treatment planning by dental providers using the EDR and the role of the EDR UI in supporting the workflow. Based on the results, we identified different issues and trends surrounding selection of dental diagnosis for the corresponding procedures being documented by dental providers.

The lack of standardized dental terminologies greatly limits the potential for flagging diagnostic-procedural links, which makes it difficult to evaluate disease patterns.³ Our results for the validity of the 10% procedure-diagnosis pairs reviewed (6187) show that 98% (733/751) of the 'not available' diagnosis could have used corresponding ICD-9-CM diagnoses. However, considering that ICD-9-CM codes are lacking in granularity or do not in all instances describe a dental condition accurately, the dental providers might have selected 'not available' in instances when they did not find the most accurate diagnosis. Similarly, there were eight procedures that had selected corresponding diagnosis that, while not inaccurate, were lacking in granularity of completeness. The following are examples: 1) CDT Amalgam-one surface, primary or permanent (D2140) had a corresponding clinical note of 'adjusting bite for sensitivity' and was coded as dental caries (521); 2) Sedative filling (D2940) with a notation in the clinical note of 'restoration fell out due to new caries' was alternatively coded as dental caries or as fractured restoration; 3) 'recementing of bridge' (D6999) had a corresponding diagnosis of 'unsatisfactory restoration' or alternatively carried a diagnosis of 'dental prosthetic device'. There were 16 procedure codes in the preventive and removable prosthodontics category of services identified as lacking a corresponding diagnosis in ICD-9-CM codes. These included, among others, dental bite registration, various intermediate steps (such as wax try-in, preliminary impressions, and final impressions involved in removable complete dentures), and patients who took expired medications. Documenting the diagnosis prior to the procedure can help in maintaining the integrity of the data. For example, documenting a treatment plan in most

EDRs now requires the dental provider to select the dental procedure (CDT codes) and then the corresponding diagnosis; however, in medical settings, the medical provider first documents the diagnosis and then the corresponding medical procedure (Current Procedure Terminology (CPT) codes).^{16,17} A standardized workflow of documentation and a similar interface design for medical and dental in the EHR serve as a uniform path to information exchange and to store structured information.

Although this data was documented under clinical notes, it becomes difficult to retrieve the information due to the unstructured format. A drop down field option consisting of the above-mentioned intermediary steps before selecting treatment procedure could help in documenting data more accurately. This could then later be turned into functional information, either by adding these codes or creating a new category of the intermediary steps to the existing diagnostic codes.

Having the ability to select multiple diagnoses, along with the capability of indicating primary diagnosis for the corresponding dental condition, would be very important and clinically significant.¹⁹ It has been recognized that oral diseases including periodontitis can influence the course and pathogenesis of systemic disease such as diabetes, Alzheimer's disease, cardiovascular diseases, and vice versa.^{20–22} The treatment for one condition having two different etiologies, such as periodontitis caused as a complication of diabetes and periodontitis caused by poor oral hygiene, may involve slightly different treatment pathways. In such cases, diagnosing and documenting the conditions (example: periodontitis, uncontrolled diabetes) before the procedure may provide an advantage for selecting alternative therapies, if required. Our results found that every CDT had only one corresponding ICD-9-CM code, attributed to the existing UI design of the EDR. Figure 3 illustrates one such proposed EDR UI design to capture multiple relevant diagnoses that was incorporated in the EDR system based on the recommendation from this study.

The treatment plan is documented by selecting a category of service—the CDTs—from the dental procedure column and then a corresponding ICD-9-CM code from the diagnoses column. The overall trend of selecting the last option from the diagnoses list without a scrollbar was seen with a higher frequency as compared with the scrollbar ($p < 0.001$). Notably, in an EDR UI without a scrollbar (representing a short list of diagnoses options for the dental providers to select from) under the diagnoses column, the 'not available' option was selected 15% (946/6140) of the time, compared to 12% (158/1323) of the time for an EDR UI with a scrollbar (representing a long list of diagnoses options for the dental providers to select from). Reasons for selecting the last option ('not available') could be due to lack of granularity in ICD9-CM codes to describe the condition and/or user interface design in searching for the corresponding diagnosis from the diagnoses column.³

Our study assessed 10% of procedure-diagnoses pairs for the appropriateness of selecting the correct diagnosis associated with the specific procedures planned by the dental providers in the EDR. The results of the study showed a dominant pattern of selecting the first or last option from the list of diagnoses. This pattern identified in our results was also reported in a study conducted by Walji et al.,¹⁶ where one of 24 high-level usability problems was the lack of complete visibility of the category and finding an appropriate concept from a long

list of items due to illogical ordering of the terms in the display screen. Notably, the selection of the first diagnosis was associated with 98% accuracy. The selection of 'not available' diagnosis by the providers showed that in 98% of instances, the accuracy was questionable. As mentioned above, the 98% inaccuracy for 'not available' diagnosis could be due to fact that diagnosis is documented after the treatment procedure and/or lack of granularity in ICD9 –CM codes to describe the conditions.

Although there were a total of 185 unique CDTs under the nine COS available for the dental providers to choose from in the procedure column of the EDR UI, only 147 unique CDTs were used during the 4 years of data considered for this study, indicating that approximately 20% of the procedures (38/185) under the CDTs were never performed in the specific dental practices under study. The design of most EDRs supports loading a common list of CDTs for all of its users. The EDR UI capabilities that would facilitate end users (dental providers) to define a customized list of CDTs most applicable for use in their individual practice based on the specific types of procedures performed will help eliminate the noise currently seen in most EDR UI designs, including the one observed in this study.

A significant statistical difference ($p < 0.001$) in selecting the 'not available' option was frequently associated with COS such as removable prosthodontics, endodontics, adjunctive general dental services, fixed prosthodontics, and implant services. These results are similar to those reported by White et al.,²⁰ who observed lowest use of diagnostic terms in COS such as implant services, orthodontics, oral surgery, and adjunctive general dental services. Considering that, historically, dental providers were never required to select a diagnosis with the procedures, and that the providers selected the 'not available' option under the diagnoses column, we hypothesize that some dental providers are having difficulty in identifying the appropriate diagnosis from the EDR and are likely selecting the last diagnosis option ('diagnosis not available'). This could be simply to satisfy the requirement for EDR documentation to move forward with the treatment plan, which was contingent on selection of a diagnosis if candidate diagnoses were available. However, we must note that a quality assurance evaluation was done for only 10% of procedure-diagnoses pairings, which showed that close to 98% of the manually validated procedure-diagnoses pairings were correct. Further assessment on all of the dataset is required to confirm this hypothesis.

Exploration of the diagnosis provided in the diagnoses column with a scrollbar and the dental provider's actions during documenting the diagnosis may signal that some searches are suboptimal and that the search environment needs to be improved in the EDR. As part of a training process, dental providers need to be informed about the various ICD-9-CM codes available for the CDT procedures that were deemed as 'not available'. Although a provider can document his/her findings in the clinical notes, having a UI that includes features for the users to provide feedback for a particular treatment next to the diagnosis may encourage users to provide additional descriptions at the point of documenting a treatment plan.

While the current EDR supports documentation of a dental diagnosis in a structured manner, developing and tailoring an EDR UI that provides fewer, more accurate diagnostic options and diagnostic terminology that is more granular and relevant to dentistry, like SNODENT (and its sub sets), should improve user intuitiveness, user satisfaction, and more importantly

documentation of accurate information at point-of-care. The use of a diagnostic-centric treatment plan, similar to that in the medical practice workflow, where the healthcare provider makes the diagnoses first and then selects the corresponding procedure, would potentially change the process of a procedure-driven approach and minimize some of the usability and data quality issues. However, it has been reported that errors were found when users were given the task to navigate a tabbed UI first to select a diagnosis and then select a treatment, possibly because of the current practice of selecting the treatment plan first and then the corresponding diagnosis.¹¹ Although a single study has been reported, more studies need to be conducted to test and confirm the exact workflow and the cognitive process of dental providers while treatment planning.

This study acknowledges some limitations. Although the dental providers documenting the dental diagnosis and procedures reflect training at a number of dental-related professional schools with varying educational teaching styles, the study data were collected at a single healthcare system and may not reflect a generalized practice behavior for documenting dental procedures and corresponding diagnoses. This raises the potential for selection bias within the healthcare system with respect to documenting and selecting diagnosis for the corresponding dental procedures. The current workflow of documenting treatment plan is procedure-driven; therefore, it would be interesting for future studies to compare an EDR UI that supports diagnostic-centric documentation vs. a procedure-driven workflow. Finally, the accuracy and causality relationship between the procedure codes and the diagnostic codes was studied for 10% of procedure-diagnoses pairs. Diagnostic terms paired with respect to the dental treatment were not checked for accuracy in terms of patient history. Similarly, the study did not look into any diagnostic terms that were frequently used¹⁸ or descriptions of the terms displayed in the EDR UI diagnoses column. Regardless of these limitations, our study reported some highly consistent trends in terms of documenting diagnoses in dental practices. This has raised several areas of usability concerns associated with documenting treatment plan within the EDR, which requires further investigation.

CONCLUSIONS

A summary of our findings was highly concordant with our premise that the EDR UI design had a great impact on documentation process. This study helps in understanding the different patterns of selecting a diagnosis for a corresponding procedure in an EDR UI that supported documenting the procedure first and then the diagnosis. A potentially useful approach is to redesign the UI to first allow the dental provider to document the diagnosis and then the corresponding procedure code(s). Also, the availability of standardized dental terminology with a list of more commonly used and pertinent diagnoses in each of the categories might be more valuable for dental providers. This study would be helpful in comparing the use of ICD-10-CM diagnostic codes, which replaced ICD-9-CM codes, as well as the use of other interface terminologies like SNODENT, DDS, and SNODDS.

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References

1. American Dental Association. [Accessed May 15, 2017] Code on Dental Procedures and Nomenclature (CDT Code). 2017. <http://www.ada.org/en/publications/cdt>
2. Centers for Disease Control and Prevention. [Accessed May 15, 2017] Introduction | Meaningful Use | CDC. 2017. <https://www.cdc.gov/ehrmeaningfuluse/introduction.html>
3. Kalenderian E, Ramoni RL, White JM, Schoonheim-Klein ME, Stark PC, Kimmes NS, Zeller GG, Willis GP, Walji MF. The development of a dental diagnostic terminology. *J Dent Educ*. 2011; 75(1):68–76. [PubMed: 21205730]
4. Leake JL. Diagnostic codes in dentistry: definition, utility, and developments to date. *J Can Dent Assoc*. 2002; 68(7):403–406. [PubMed: 12119089]
5. Goldberg LJ, Ceusters W, Eisner J, Smith B. The significance of SNODENT. *Stud Health Technol Inform*. 2005; 116:737–742. [PubMed: 16160346]
6. Leake JL, Main PA, Sabbah W. A system of diagnostic codes for dental health care. *J Public Health Dent*. 1999; 59(3):162–170. [PubMed: 10649589]
7. Rudman W, Hart-Hester S, Jones W, Caputo N, Madison M. Integrating medical and dental records: a new frontier in health information management. *J. AHIMA*. 2010; 81(10):36–39.
8. Powell, VJ., Din, FM. Call for an integrated (medical/dental) health care model that optimally supports chronic care, pediatric care, and prenatal care as a basis for 21st century EHR standards and products: EHR position paper. Robert Morris University; Pittsburgh, PA: 2008. p. 1-51. http://www.himss.org/sites/himssorg/files/HIMSSorg/policy/d/hc_comm_discussion/MoonTownshipPennPositionPaper.pdf [Accessed May 15, 2017]
9. Kalenderian, E., Walji, M., Ramoni, R. Applying HCI Principles in Designing Usable Systems for Dentistry. In: Patel, VL. Kannampallil, TG., Kaufman, DR., editors. *Cognitive Informatics for Biomedicine: Human Computer Interaction in Healthcare*. Switzerland: Springer International; 2015. p. 189-213.
10. American Dental Association. [Accessed May 15, 2017] SNODENT Systematized Nomenclature of Dentistry: SNODENT Value and Benefits. 2017. <http://www.ada.org/en/member-center/member-benefits/practice-resources/dental-informatics/snodent/snodent-value-and-benefits>
11. Brailo V, Firriolo FJ, Tanaka TI, Varoni E, Sykes R, McCullough M, Hua H, Sklavounou A, Jensen SB, Lockhart PB, Mattsson U, Jontell M. World Workshop on Oral Medicine VI: Utilization of Oral Medicine-specific software for support of clinical care, research, and education: current status and strategy for broader implementation. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2015; 120(2):172–184. [PubMed: 25843941]
12. Manchir, M. [Accessed May 15, 2017] Newly approved standard enables electronic capture of patient diagnoses. *ADA News Archive*. 2017. <http://www.ada.org/en/publications/ada-news/2016-archive/december/newly-approved-standard-enables-electronic-capture-of-patient-diagnoses>
13. Schleyer T, Song M, Gilbert GH, Rindal DB, Fellows JL, Gordan VV, Funkhouser E. Electronic dental record use and clinical information management patterns among practitioner-investigators in The Dental Practice-Based Research Network. *J Am Dent Assoc*. 2013; 144(1):49–58. [PubMed: 23283926]
14. Acharya A. Marshfield Clinic Health System: Integrated Care Case Study. *J Calif Dent Assoc*. 2016; 44(3):177–181. [PubMed: 27044239]
15. McCarthy D, Mueller K, Klein S. Marshfield Clinic: Health Information Technology Paves the Way for Population Health Management. *The Commonwealth Fund*. 2009; 1293 [Accessed May 15, 2017] http://www.commonwealthfund.org/~media/files/publications/case-study/2009/aug/1293_mccarthy_marshfield_case_study.pdf.

16. Russo, R. [Accessed May 15, 2017] Documentation and Data Improvement Fundamentals. IFHRO Congress & AHIMA Convention Proceedings. 2004. <http://bok.ahima.org/doc?oid=60174#.WUqEUevyteM>
17. American Dental Association. [Accessed May 15, 2017] Electronic Health Records FAQs. 2011. <http://www.cda.com/docs/default-source/regulations/electronic-health-records.pdf?sfvrsn=0>

File Setup Lists Tools Help

Select Patient Commlog Letter Label Special Conditions

Appts Lab Perio Chart Post Completed Procedures Clinical Note Digital Imaging Alerts

Provider: Dental Center, Park Falls

Enter Treatment Primary Planned Appointment Show Tooth Chart Legend

Add Procedure

Category: Dentist Procedure: Search...

•Amalgam
 •Composite
 •Root Canal
 •Complete Dent- Maxilla
 •Complete Dent- Mandib
 •Immediate Dent- Maxilla
 •Immediate Dent- Mandib
 •Part Resin Base- Maxilla
 •Part Resin Base- Mandib
 •Part Metal Base- Maxilla
 •Part Metal Base- Mandib
 •Part Flex Base- Maxilla
 •Part Flex Base- Mandib
 •Ext Cml Remints-Decid
 •Extract Erupted Th/Rt
 •Extract- Surgical

Diagnosis

Caries, into pulp
 Attrition, pulp
 Abrasion, pulp
 Erosion, pulp
 Resorption, interm
 Cracked tooth
 Pulpitis
 Pulp necrosis
 Pulp degeneration
 Pulp calcification
 Acute apical perio
 Peri abscess, no sinus
 Peri abscess, sinus

Attributes

☐ Supernumerary
☐ Attach to Referral

Commit Treatment

TxPlan Comp Refer Existing

patient is a gagger

Dental Alerts

None

Active Medications

Last Updated

02/02/10 Acetaminophen
 02/02/10 Acetaminophen-Codeine 300-30mg Tablet 1 or 2 Tab...
 01/14/10 Amoxicillin 125mg/5 mL Suspension for Reconstitution ...
 01/14/10 Fluoride (Sodium Fluoride) 1 (2.2)mg Tablet, Chewa...

Allergies/Adverse Reactions - Clinical Alerts

Drug (Verified 01/07/2010 By)

Amoxicillin: Diarrhea / as child
 Amoxicillin/Clavulanic Acid (Augmentin®)
 Benzocaine (local caines anesthetics): Reaction unknown by patient / as
 Penicillin

Non-Drug (Verified 02/02/2010 By)

No Known Non-Drug Allergies/Adverse Reactions (NKNDRA)

Clinical Alerts

None

Progress Notes

Date	Th	Surf	Code	Description	Stat	Amount
02/02/2010	7	MID	D2160		RC	
02/02/2010	1	MODL	D2161		EO	
02/02/2010			Zreferral		R	
02/01/2010	14		D1351		TP	
02/01/2010	15		D1351		TP	
02/01/2010	16		D1351		TP	
02/01/2010	17		D1351		TP	
02/01/2010	18		D1351		TP	

Event Date Description Note

Patient Registration & HIM Consent Form | Health/Dental History & Health History Update | Dental Care Consent Form | Referrals/Follow-up Letters

Figure 1.
Re-designed Electronic Dental Record User Interface to capture ICD9 Dental Diagnosis

Figure 2.

Sections of the EDR UI and various EDR UI designs under the diagnosis column based on the length of the candidate diagnostic list.

Enter Treatment Primary Planned Appointment Movement Show Tooth Chart Legend

Add Procedure

Category: Procedure: [Search...](#)

Z Codes

Conditions

Other

Diagnostic

Preventive

Restorative

• 1/2Prophy

• 1/2Prophy

• Oral Hyg Inst

• PreventiveApptZ

• ProphyAdult 13+

• ProphyChild(0-12yrs)

• RecementSpaceMain

Attributes

☐ Super-numerary

☐ Attach to Referral

Secondary Provider

Surfaces

B/F V

M O/I D

L

Add

Clear

Commit Treatment

TxPlan | ▾ Comp. | ▾

Refer | ▾ Existing

Figure 3.

Proposed EDR UI design to capture multiple relevant diagnoses that was incorporated in the EDR system based on the recommendation from the study

Table 1

Distribution of the total number of dental procedures across the nine CDT categories of service and the corresponding numbers and percentages of documented 'available' and 'not available' diagnosis, unique CDT and unique ICD-9-CM codes.

Category of services (COS)	Total number of procedures performed	Number and Percentage of 'available' option (%) selected	Number and Percentage of 'not available' option (%) selected	Total number of unique CDT code used	*Total number of unique ICD-9-CM code used per COS	P-value
Diagnostic	47,858	43,775(91.5%)	4,083(8.5%)	22	8	<0.001
Restorative	7,456	6,353(85.2%)	1,103(14.8%)	33	29	<0.001
General	3,220	2,528(78.5%)	692(21.5%)	18	20	<0.001
Periodontics	1,455	1,039(71.4%)	416(28.6%)	10	9	<0.001
Prosthodontics Removable	862	398(46.2%)	464(53.8%)	34	10	<0.001
Preventive	496	418(84.3%)	78(15.7%)	8	6	<0.001
Endodontics	127	76(59.8%)	51(40.2%)	8	16	0.03
Prosthodontics	23	10(43.5%)	13(56.5%)	9	3	0.68
Implant Services	14	0(0%)	14(100%)	5	0	0.0005
Total	61,511	54,597(88.8%)	6,914(11.2%)	147	N/A	

* Total number of unique ICD-9CM codes do not include 'not available' diagnosis. Similarly total number of unique ICD codes is different than the total number of unique ICD 9 codes used per category of service

CDT, Code on Dental Procedure and Nomenclature
ICD-9-CM, International Classification of Disease, Ninth Revision, Clinical Modification

Table 2

Results of the manual evaluation of the accuracy of the 10% of procedures-diagnosis pairing

Category of Service (COS)	Total number				
	Total number of CDT/ICD-9 Pairs for manual validation (A) (A=B+C+D+E)	Total number of diagnosis selected from the 'available' option' (B)	Total number of diagnosis selected from the 'available' option which could have been documented under a more specific ICD 9 code (C)	Total number of diagnosis selected as 'Not available' where ICD 9 code does exist* (D)	Total number of diagnosis selected as 'not available', for which ICD 9 CM codes do not exist (E)
Diagnostic	4786	4351	3	432	0
Endodontics	13	9	0	4	0
General	322	249	0	73	0
Implants	14	0	0	14	0
Periodontics	146	105	0	41	0
Preventive	50	42	0	5	3
Prosthodontics, Removable	87	33	0	41	13
Prosthodontics, Fixed	23	8	2	13	0
Restorative	746	631	3	112	0

CDT, Code on Dental Procedure and Nomenclature
ICD-9-CM, International Classification of Disease, Ninth Revision, Clinical Modification

* based on documentation in the clinical notes of diagnostic and procedural definitions, an ICD9 code may have been available for selection but may not have been selected due to perceived lack of granularity.