Evaluating a Dental Diagnostic Terminology in an Electronic Health Record

Joel M. White, D.D.S., M.S.; Elsbeth Kalenderian, D.D.S., M.P.H.;
Paul C. Stark, M.S., Sc.D.; Rachel L. Ramoni, D.M.D., Sc.D.;
Ram Vaderhobli, B.D.S., M.S.; Muhammad F. Walji, Ph.D.

Abstract: Standardized treatment procedure codes and terms are routinely used in dentistry. Utilization of a diagnostic terminology is common in medicine, but there is not a satisfactory or commonly standardized dental diagnostic terminology available at this time. Recent advances in dental informatics have provided an opportunity for inclusion of diagnostic codes and terms as part of treatment planning and documentation in the patient treatment history. This article reports the results of the use of a diagnostic coding system in a large dental school's predoctoral clinical practice. A list of diagnostic codes and terms, called Z codes, was developed by dental faculty members. The diagnostic codes and terms were implemented into an electronic health record (EHR) for use in a predoctoral dental clinic. The utilization of diagnostic terms was quantified. The validity of Z code entry was evaluated by comparing the diagnostic term entered to the procedure performed, where valid diagnosis-procedure associations were determined by consensus among three calibrated academically based dentists. A total of 115,004 dental procedures were entered into the EHR during the year sampled. Of those, 43,053 were excluded from this analysis because they represent diagnosis or other procedures unrelated to treatments. Among the 71,951 treatment procedures, 27,973 had diagnoses assigned to them with an overall utilization of 38.9 percent. Of the 147 available Z codes, ninety-three were used (63.3 percent). There were 335 unique procedures provided and 2,127 procedure/diagnosis pairs captured in the EHR. Overall, 76.7 percent of the diagnoses entered were valid. We conclude that dental diagnostic terminology can be incorporated within an electronic health record and utilized in an academic clinical environment. Challenges remain in the development of terms and implementation and ease of use that, if resolved, would improve the utilization.

Dr. White is Professor, Department of Preventive and Restorative Dental Sciences, School of Dentistry, University of California, San Francisco; Dr. Kalenderian is Assistant Dean for Clinical Affairs, Department of Oral Health Policy and Epidemiology, Harvard School of Dental Medicine; Dr. Stark is Associate Professor, Department of Research Administration, and Director of Advanced and Graduate Education, School of Dental Medicine, Tufts University; Dr. Ramoni is Program Director, Department of Oral Health Policy and Epidemiology, Harvard School of Dental Medicine; Dr. Vaderhobli is Health Sciences Assistant Professor, Department of Preventive and Restorative Dental Sciences, School of Dentistry, University of California, San Francisco; and Dr. Walji is Assistant Professor of Diagnostic Sciences, Dental Branch, University of Texas Health Science Center at Houston. Direct correspondence and requests for reprints to Dr. Joel M. White, School of Dentistry, University of California, San Francisco, 707 Parnassus Avenue, Box 0758 D-3248, San Francisco, CA 94143-0758; 415-476-0918; whitej@dentistry.ucsf.edu.

Diagnostic codes in medicine are used to collect, identify, and classify diseases, disorders, medical signs, and symptoms.[1] During the 1950s, Ledley and Lusted focused on the development of a diagnostic system.[2] Today, the standard accepted diagnostic terminology in medicine associated with completed treatment procedure codes is the International Classification of Disease (ICD, which is maintained by the World Health Organization). Despite its widespread use globally and the inclusion of some oral health diagnoses, the ICD does not have sufficient coverage due to the lack of specificity for oral and dental diagnoses.[3,4] More recently, the Systematized Nomenclature of Medicine Clinical Terms (SNOMED-CT), a more comprehensive clinical terminology that includes diagnoses, is also gaining adoption and is considered a standard by the U.S. government for clinical conditions and problem lists. However, SNOMED-CT also has a limited number of oral health concepts related to diagnoses.

Dentistry currently lacks an accepted vocabulary to classify and identify dental diseases. A standardized dental diagnostic terminology would provide many benefits for teaching the relationship between disease and treatment procedures and the rationale for providing patient care and for conducting data analysis for research purposes. In contrast, pro-

cedure or treatment codes have long been standardized by the dental profession and are used routinely as part of billing procedures using the standardized and accepted American Dental Association (ADA) Current Dental Terminology (CDT),[5] which contains the Code on Dental Procedures & Nomenclature. These codes and terms are used to document and communicate accurate information about dental treatment procedures and services. Dentistry therefore has excellent records on what procedures were actually performed on patients, but little to no standardized diagnostic terminology giving the rationale for why those procedures were done.

Because medically based vocabularies like ICD and SNOMED are not comprehensive for oral health, there have been attempts in the past to create a dental diagnostic terminology.[6] For example, the Systematized Nomenclature of Dentistry (SNODENT) is an effort of the ADA to develop a standardized terminology that overcomes the limitations of the ICD system and addresses the needs of clinical dentistry for routine use. Though SNODENT was initiated in the early 1990s and was incorporated into SNOMED, now maintained and freely available in the United States through the National Library of Medicine, SNODENT codes in SNOMED are limited in scope and are not frequently used.[3] Furthermore, early analyses of the vocabulary suggest that SNODENT's coverage of dental findings and diagnoses has gaps,[4,7] and no rigorous evaluations have been published about the diagnostic coding system utilized by SNODENT.[7] The ADA is currently revising the original SNODENT codes, and SNODENT II is available on a limited basis for evaluation and initial testing. In Canada, a diagnostic system was developed and utilized in a public health system, but this system was not adopted or used by others.[8]

A factor facilitating coding dental diagnoses is the increased adoption of electronic health records (EHR). EHRs in dentistry allow providers to electronically create, store, organize, edit, and retrieve patients' oral health information. Although a minority of private practice dentists use EHRs, close to 87 percent of general dentists use a computer in their private practice.[9] Adoption of EHRs amongst dental schools is high, and the opportunity to utilize diagnostic codes for enhancing student clinical training, fostering evidence-based practice, and conducting research has interested many academic dental institutions. Further, fifty of the fifty-six U.S. dental schools, as well as dental schools in Canada and Europe, use or plan to use some aspects of a common dental EHR platform (axiUm, Exan Corporation, Vancouver, BC, Canada).

In 2007, a consortium of dental schools, the Consortium for Oral Health-Related Informatics (COHRI), was formed to standardize, share data, and develop efficiencies and tools within the EHR to help educate students, care for patients, and conduct innovative research.[10] One primary long-term goal of COHRI is to develop and implement a standardized dental diagnostic vocabulary. Currently, most dental schools document diagnoses in an EHR through a free text note in an unstructured format or through manual chart entries. Thus, COHRI recognized that a major gap exists in dentistry's ability to document dental diagnoses in a standardized way.[7] However, one COHRI member school, the University of California, San Francisco, School of Dentistry (UCSF), has already pioneered and implemented the use of diagnostic codes in its EHR since 2000. As a first step, the objective of this article was to report on how successfully a locally developed dental diagnostic system was used and to identify challenges and barriers. Findings from this analysis are expected to contribute to the development and utilization of a standardized diagnostic vocabulary for dentistry.

Materials and Methods

The Z codes were developed over a period of two years by combining and expanding upon diagnostic terms from the Toronto System[8] and relevant terms from the ICD. A group of general and specialist dental faculty members at UCSF reviewed and refined this listing, adding additional terms to expand term coverage. These Z codes included a finer granularity of the extent of caries, defining two stages of enamel caries and three levels of dentinal caries. In addition, diagnoses were added that encompassed the need for tooth restoration and tooth replacement, such as fractured tooth and biologically unacceptable restoration. Ultimately, 147 discrete terms were included. The diagnostic terms were grouped by discipline: periodontology, caries, restorative dentistry, endodontics, fixed and removable prosthodontics, oral medicine, and oral surgery. The numerical codes assigned to each term were nonsemantic, i.e., they did not represent any particular structure of diagnosis.

The dental diagnostic terminology was encoded as Z codes and loaded into the EHR software system. Three types of diagnoses could be assigned: tentative, working, and definitive. During treatment planning,

tentative diagnoses were first entered by selecting all of the relevant diagnoses that pertained to a specific patient from the listing of Z codes. Each diagnosis was selected for a specific planned treatment (procedure) during treatment planning. For instance, Figure 1 shows the selection of gingivitis during the building of a detailed treatment plan, which could be assigned to the procedure prophylaxis. The dental faculty member supervising the student providers reviewed and approved the treatment plans and selected diagnoses.

Working and definitive diagnoses, on the other hand, were selected and assigned to a specific dental procedure in a customized field called "clinical1." The working diagnosis was able to be related directly to a specific tooth and surface procedure, such as tooth #3-Occlusal-1 surface posterior composite, as shown in Figure 2. Entering the working diagnosis

in field "clinical1" allowed the working diagnosis to be changed to the definitive diagnosis at the time the procedure was performed. The tentative diagnosis entered in the treatment planning module was not modifiable at the time of treatment, so in order to enter a diagnosis that could be modified, clinicians had to enter the working diagnosis in the custom field "clinical1."

Training in the use of the axiUm EHR occurred as part of the second-year dental curriculum. Students were trained in all aspects of developing an electronic dental record using test patients. The Z codes were available to all student providers. The use of the diagnostic terms and Z codes was at the discretion of the student providers and their supervising faculty members. This is consistent with other aspects of the EHR: that use of any specific aspect of the record is based on the requirements of good clinical practice
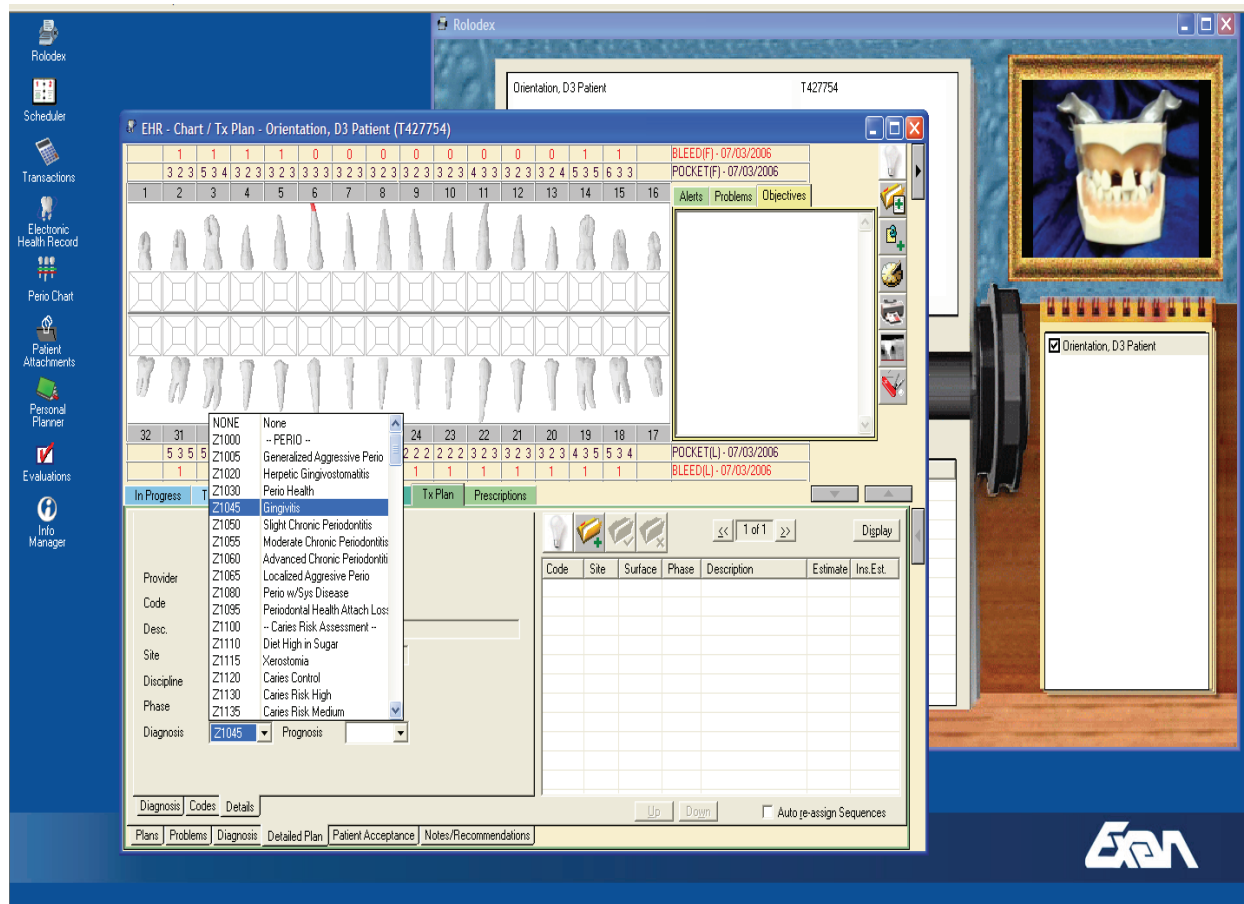

Figure 1. Selecting a Z Code in the EHR at the treatment planning stage
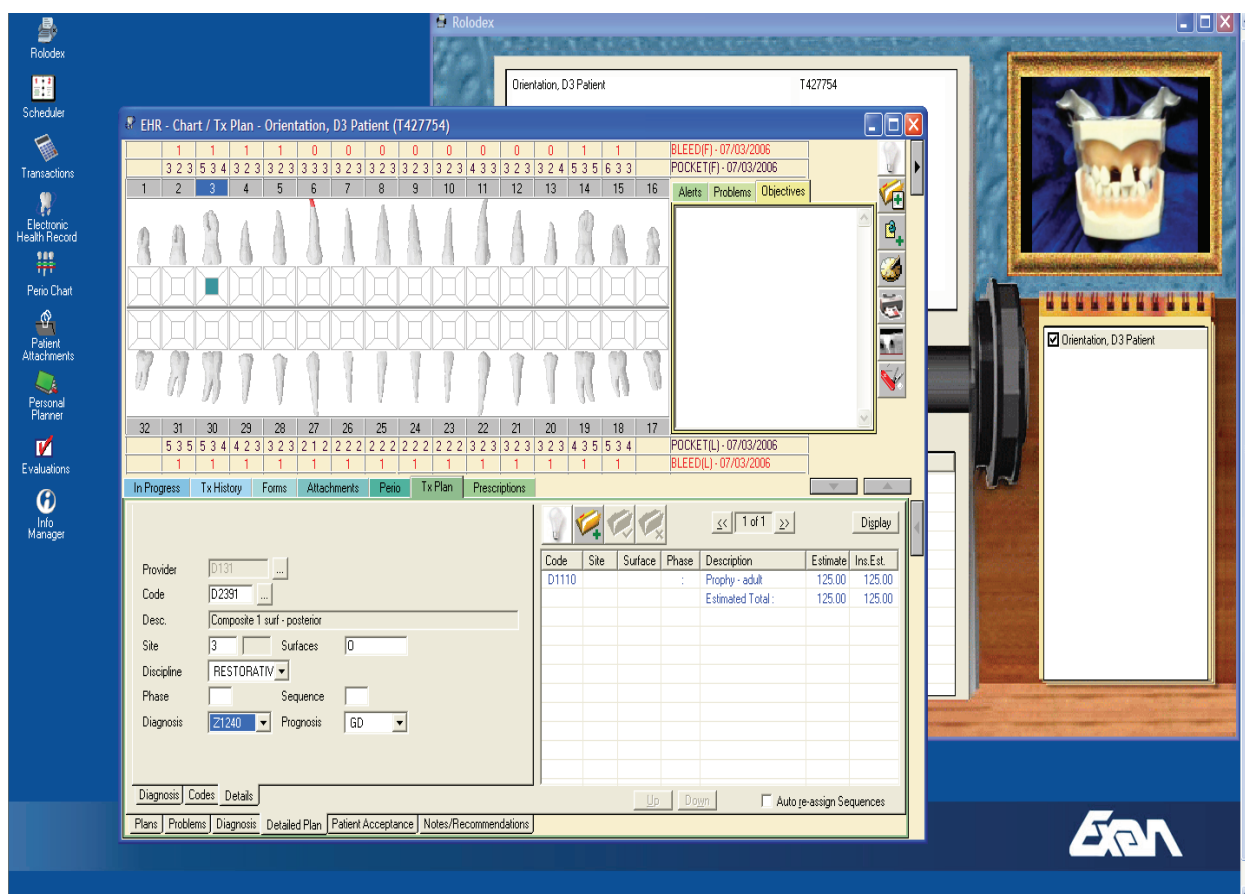
Figure 2. Entering working diagnosis into the EHR

as taught by the faculty but is not mandatory (i.e., a "forced function" in the EHR).

In order to analyze the utilization of the diagnostic codes, all patient visits and associated coding utilized from 7/1/2007 through 6/30/2008 in the predoctoral clinics at UCSF were analyzed. The codes included all diagnostic codes entered by student providers including tentative diagnosis in the treatment plan, working diagnosis, and definitive diagnosis associated with specific procedures in the EHR.

The validation of the diagnostic term entry was performed by determining valid diagnostic-procedure combinations. For instance, "gingivitis" can be validly associated with the procedure "prophylaxis," but it would not be valid to associate it to a "posterior one-surface composite" procedure, as filling is not an appropriate treatment for the diagnosis of "gingivitis." The entry of standardized treatment codes

(ADA Current Dental Terminology, Code on Dental Procedures & Nomenclature)[5] is closely supervised in the dental clinic. The assessment of valid diagnostic terms-procedure pairs was performed by three independent, trained, calibrated faculty dentists. The dentists were trained in use of the diagnostic terms and had a working knowledge of standard dental practice, including the Code on Dental Procedures & Nomenclature. Each observer was given a list of the Code on Dental Procedures & Nomenclature and all the associated Z codes and terms that were used with these procedures. Each observer independently rated each relationship as valid or not valid. Subsequently, the observers met to adjudicate their assessments, yielding a final procedure code-diagnostic term relationship. The individual observers' ratings were compared with the adjudicated data to determine the degree of agreement.

For utilization and validation analyses, we considered only definitive diagnosis as captured in custom field "clinical1" and non-diagnostic procedures (treatment procedures) at the time the treatment procedures were completed. It was felt by the investigators that ascribing a diagnosis for diagnostic procedures, such as an oral exam, would be inappropriate and could yield a variety of inaccurate diagnoses. Descriptive statistics of overall utilization and validity were calculated. Overall and within each category of diagnosis, we determined the number and proportion of instances in which a diagnosis was entered. Among the instances in which a Z code was entered, we calculated the number and proportion of occasions in which it was correct. These analyses were conducted in SAS version 9.2 (SAS Institute Inc., Cary, NC).

Results

A total of 115,004 dental procedures were entered into the EHR during the year sampled. Of the 147 available diagnostic terms (Z codes), ninety-three were used (63 percent), indicating that 37 percent of the codes were never used. Of the procedures, 43,053 were diagnostic, leaving 71,951 non-diagnostic treatment procedures for analysis. Among these procedures, 27,973 had diagnoses assigned to them, yielding a utilization of 38.9 percent. Results were then stratified by procedure type (preventive, restorative, endodontic, periodontal, removable prosthodontics, implant, fixed prosthodontics, oral surgery, orthodontic, and adjunctive), as listed within the Code on Dental Procedures & Nomenclature.[5] Restorative, periodontal, and endodontic procedures had the highest utilization of diagnostic terms, followed by removable and fixed prosthodontics and preventive procedures. The lowest utilization was dental implants, orthodontics, oral surgery, and adjunctive general dental services, all of which also had low sample sizes. Full results are shown in Table 1.

The three individual observers' (n=2,539 diagnosis-procedure pairs per observer) ratings were compared with the adjudicated data to determine the degree of agreement. One observer had a Kappa of 0.098, indicating slight agreement; one observer had a Kappa of 0.522, indicating moderate agreement; and one observer had a Kappa of 0.888, indicating almost perfect agreement to the adjudicated diagnosis-procedure pairs.[11]

For the 38.9 percent of procedures and diagnostic terms utilized, the overall validity was 76.7 percent. Analysis of the procedure-diagnosis combinations demonstrated that, of the 27,973 diagnostic terms entered, 21,463 (76.7 percent) were valid. Thus, the error rate was 22.3 percent. Stratified by discipline, periodontal diagnosis-procedures

Table 1. Utilization and validity of entry of diagnostic terms

Area (CDT code range)	Dental Procedures (CDT)	No Diagnosis Entered	Diagnosis Entered	Diagnosis Correct	Utilization	Validity
Overall	71,951	43,978	27,973	21,463	38.9%	76.7%
Preventive (D1000–D1999)	10,986	7,229	3,757	1,838	34.2%	48.9%
Restorative (D2000–D2999)	29,917	15,939	13,978	11,856	46.7%	84.8%
Endodontic (D3000–D3999)	2,478	1,356	1,122	900	45.3%	80.2%
Periodontal (D4000–D4999)	6,120	3,322	2,798	2,594	45.7%	92.7%
Prosthodontic, Removable (D5000–D5899)	5,745	3,239	2,506	2,236	43.6%	89.2%
Dental Implant (D6000–D6199)	316	263	53	42	16.8%	79.3%
Prosthodontic, Fixed (D6200–D6999)	2,043	1,236	807	627	39.5%	77.7%
Oral Surgery (D7000–D7999)	2,501	2,069	432	264	17.3%	61.1%
Orthodontic (D8000–D8999)	22	18	4	1	18.0%	25.0%
Adjunctive General Service (D9000–D9999)	11,823	9,307	2,516	1,105	21.3%	43.9%

combinations had the highest validity, followed by removable prosthetics and restorative dentistry. The lowest validity (25 percent) was achieved in orthodontics, but only 22 orthodontic procedures were performed (Table 1).

The most frequently used procedure and diagnostic code pairs are shown in Tables 2–9. These tables show the number of diagnostic codes and descriptions chosen by providers, by discipline.

For preventive services, the most commonly chosen procedure was an "adult prophylaxis," with diagnostic descriptions of "gingivitis" and "periodontal health," adjudicated as accurate. The pairs of "adult prophylaxis" and "slight chronic periodontitis" and "adult prophylaxis" and "moderate chronic periodontitis" were deemed inaccurate by the evaluators (Table 2).

For restorative services, the most frequently used diagnostic codes and descriptions were associated with "caries." Caries diagnosis was classified as "caries pit fissure," "caries to the dentinal-enamel junction DEJ," "caries less than half way to the pulp," "caries greater than half way to the pulp," and "recurrent caries." Other non-carious diagnostic descriptions utilized were "fracture in enamel," "fracture of enamel and dentin," and "abfraction." For the most part, "caries" and fracture diagnostic descriptions were adjudicated as accurately paired with the restorative procedures performed. Some inaccurate procedure diagnostic pairs occurred when providers chose "caries risk," "necrosis of the pulp," "simple enamel fracture," and the general caries description (Table 3).

For endodontic procedures, the validated associated diagnostic descriptions were "caries greater than halfway to the pulp," "caries to the pulp," "pulpal necrosis," and "irreversible pulpitis." The inaccurate associated diagnostic descriptions were "reversible pulpitis," "caries less than half way to the pulp," and the general diagnosis of caries for single-rooted and multi-rooted root canal procedures (Table 4).

Periodontal procedures of "scaling and root planing" and "periodontal maintenance" were most commonly associated with periodontal disease diagnostic descriptions of "slight, moderate, and chronic advanced periodontitis." The most frequent inaccurate association was "periodontal maintenance procedure" paired with the "periodontal health" diagnostic description (Table 5).

The most frequently used diagnostic description was "missing teeth" for the removable prosth-

odontic procedures. There were no frequently used inaccurate diagnostic descriptions associated with removable prosthodontics (Table 6).

For fixed prosthodontic procedures, the most frequently used diagnoses were "caries," "fracture," "restoration fracture," and "restoration open margin." For fixed prosthesis abutments, the inaccurate associated diagnostic descriptions were "necrosis of the pulp," "missing teeth," and "simple fracture of enamel." Inaccurate diagnostic descriptions associated with pontics were "recurrent caries" and "advanced chronic periodontitis" (Table 7).

The most frequently used procedures for oral surgery procedures were "single tooth extraction" and "each additional tooth extraction." The most frequently used diagnostic descriptions were "advanced chronic periodontitis" and "caries to the pulp" (Table 8).

For adjunctive general services, the most frequently used procedures were the "emergency palliative examination" and "dispensing of fluoride and chlorhexidine." This area of services had low agreement between observers, due to the diagnostic descriptions of caries risk and caries activity (Table 9).

Discussion

We have reported on the development, implementation, utilization, and agreement of a comprehensive dental diagnostic terminology, Z codes. The Z codes were designed to be richer and more specific than existing dental diagnostic terminologies and were readily available to the dental clinicians in the EHR. These efforts resulted in a high valid utilization rate of 76.7 percent.

The descriptions, concepts, vocabulary, and terms encompassed by the Z codes were developed by faculty members who were keenly interested in adequately reflecting diagnoses in a systematic way. The diagnostic descriptions encompassed a broad definition of health, disease, and predisposition of disease. Included within the diagnostic descriptions were health, diseases, conditions, problems, disorders, deformities, and findings that lead clinicians to make decisions regarding specific treatment procedures to be performed. This broader definition was included as we wanted to capture the reasoning for the selection of treatment procedures and provide for the most accurate description. The diagnostic descriptions developed included specific diseases in

Table 2. Most frequently used preventive procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
1110	prophy adult	Z1045	Gingivitis	734	1
1110	prophy adult	Z1030	Periodontal Health	485	1
1110	prophy adult	Z1050	Slight Chronic Periodontitis	400	0
1110	prophy adult	Z1055	Moderate Chronic Periodontitis	388	0

Table 3. Most frequently used restorative procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
2391	Composite 1 surf.-post.-perm.	Z1235	Caries Pit Fissures (1)	453	1
2391	Composite 1 surf.-post.-perm.	Z1285	Abfraction	362	1
2391	Composite 1 surf.-post.-perm.	Z1240	Caries DEJ (2)	333	1
2391	Composite 1 surf.-post.-perm.	Z1245	Caries -.5 Pulp (3)	320	1
2330	Composite 1 surf.-ant.	Z1245	Caries -.5 Pulp (3)	274	1
2330	Composite 1 surf.-ant.	Z1240	Caries DEJ (2)	253	1
2392	Composite 2 surf.-post.-perm.	Z1245	Caries -.5 Pulp (3)	250	1
2330	Composite 1 surf.-ant.	Z1220	Recurrent Caries	249	1
2392	Composite 2 surf.-post.-perm.	Z1240	Caries DEJ (2)	245	1
2150	Amalgam, 2 surf.	Z1245	Caries -.5 Pulp (3)	208	1
2150	Amalgam, 2 surf.	Z1240	Caries DEJ (2)	203	1
2150	Amalgam, 2 surf.	Z1220	Recurrent Caries	198	1
2392	Composite 2 surf.-post.-perm.	Z1220	Recurrent Caries	176	1
2330	Composite 1 surf.-ant.	Z1285	Abfraction	172	1
2140	Amalgam, 1 surf.	Z1245	Caries -.5 Pulp (3)	168	1
2331	Composite 2 surf.-ant.	Z1220	Recurrent Caries	165	1
2331	Composite 2 surf.-ant.	Z1240	Caries DEJ (2)	160	1
2140	Amalgam, 1 surf.	Z1235	Caries Pit Fissures (1)	155	1
2330	Composite 1 surf.-ant.	Z1230	Caries Smooth Enamel	151	1
2140	Amalgam, 1 surf.	Z1240	Caries DEJ (2)	148	1
2330	Composite 1 surf.-ant.	Z1210	Root Caries	147	1
2331	Composite 2 surf.-ant.	Z1245	Caries -.5 Pulp (3)	138	1
2140	Amalgam, 1 surf.	Z1220	Recurrent Caries	122	1
2950	Crown buildup, plastic	Z1220	Recurrent Caries	72	1
2950	Crown buildup, plastic	Z1260	Fracture: Dentin (II)	54	1
2950	Crown buildup, plastic	Z1320	Restoration Fracture	39	1
2950	Crown buildup, plastic	Z1250	Caries +.5 Pulp (4)	37	1
2950	Crown buildup, plastic	Z1245	Caries -.5 Pulp (3)	33	1
2391	Composite 1 surf.-post.-perm.	Z1200	CARIES	58	0
2331	Composite 2 surf.-ant.	Z1230	Caries Smooth Enamel	42	0
2392	Composite 2 surf.-post.-perm.	Z1230	Caries Smooth Enamel	42	0
2392	Composite 2 surf.-post.-perm.	Z1200	CARIES	36	0
2331	Composite 2 surf.-ant.	Z1200	CARIES	24	0
2950	Crown buildup, plastic	Z1540	Necrosis of Pulp	18	0
2950	Crown buildup, plastic	Z1255	Fracture: Enamel (I)	15	0
2331	Composite 2 surf.-ant.	Z1130	Caries Risk High	14	0

Table 4. Most frequently used endodontic procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
3320	Bicuspid RCT-single root	Z1540	Necrosis of Pulp	89	1
3330	Molar RCT	Z1540	Necrosis of Pulp	89	1
3330	Molar RCT	Z1515	Irreversible Pulpitis	88	1
3330	Molar RCT	Z1215	Caries to the Pulp	63	1
3320	Bicuspid RCT-single root	Z1215	Caries to the Pulp	59	1
3320	Bicuspid RCT-single root	Z1515	Irreversible Pulpitis	46	1
3320	Bicuspid RCT-single root	Z1250	Caries +.5 Pulp (4)	40	1
3321	Bicuspid RCT-multi root	Z1540	Necrosis of Pulp	8	1
3321	Bicuspid RCT-multi root	Z1215	Caries to the Pulp	7	1
3321	Bicuspid RCT-multi root	Z1515	Irreversible Pulpitis	6	1
3321	Bicuspid RCT-multi root	Z1250	Caries +.5 Pulp (4)	1	1
3320	Bicuspid RCT-single root	Z1245	Caries -.5 Pulp (3)	13	0
3320	Bicuspid RCT-single root	Z1200	CARIES	11	0
3320	Bicuspid RCT-single root	Z1530	RCT Trmt-Periapical Health	11	0
3321	Bicuspid RCT-multi root	Z1245	Caries -.5 Pulp (3)	1	0
3321	Bicuspid RCT-multi root	Z1535	Reversible Pulpitis	1	0

Table 5. Most frequently used periodontal procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
4341	Scaling/root planing by quad	Z1055	Moderate Chronic Periodontitis	979	1
4341	Scaling/root planing by quad	Z1060	Advanced Chronic Periodontitis	647	1
4341	Scaling/root planing by quad	Z1050	Slight Chronic Periodontitis	221	1
4910	Perio maintenance	Z1055	Moderate Chronic Periodontitis	141	1
4910	Perio maintenance	Z1060	Advanced Chronic Periodontitis	84	1
4341	Scaling/root planing by quad	Z1030	Perio Health	31	0
4341	Scaling/root planing by quad	Z1000	PERIO	25	0
4910	Perio maintenance	Z1095	Periodontal Health Attach Loss	14	0
4910	Perio maintenance	Z1030	Perio Health	11	0

Table 6. Most frequently used removable prosthodontic procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
5110	Complete denture-max.	Z1405	Missing Teeth	435	1
5215	LPD Metal Base, Distal Ext	Z1405	Missing Teeth	310	1
5309	Teeth U/L Stayplate (706)	Z1405	Missing Teeth	252	1
5120	Complete denture-mand.	Z1405	Missing Teeth	212	1

Table 7. Most frequently used fixed prosthodontic procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
2750	PFM high noble metal	Z1220	Recurrent Caries	356	1
2750	PFM high noble metal	Z1260	Fracture: Dentin (II)	197	1
2790	Full cast high noble metal	Z1220	Recurrent Caries	197	1
6750	Abutment Porc.-fused high noble	Z1405	Missing Teeth	177	1
2750	PFM high noble metal	Z1320	Restoration Fracture	153	1
2750	PFM high noble metal	Z1335	Restore Open Margin	145	1
6240	Pontic-Porc.-fused high noble	Z1405	Missing Teeth	141	1
2790	Full cast high noble metal	Z1260	Fracture: Dentin (II)	110	1
2790	Full cast high noble metal	Z1320	Restoration Fracture	100	1
2750	PFM high noble metal	Z1540	Necrosis of Pulp	53	0
2750	PFM high noble metal	Z1405	Missing Teeth	35	0
6240	Pontic-Porc.-fused high noble	Z1220	Recurrent Caries	28	0
2790	Full cast high noble metal	Z1255	Fracture: Enamel (I)	23	0
2790	Full cast high noble metal	Z1405	Missing Teeth	13	0
6750	Abutment Porc.-fused high noble	Z1060	Advanced Chronic Periodontitis	10	0

Table 8. Most frequently used oral surgery procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
7120	Extraction Each add tooth	Z1060	Advanced Chronic Periodontitis	58	1
7110	Extraction Single tooth	Z1060	Advanced Chronic Periodontitis	48	1
7110	Extraction Single tooth	Z1215	Caries to the Pulp	11	1
7120	Extraction Each add tooth	Z1405	Missing Teeth	23	0

Table 9. Most frequently used adjunctive general service procedure-diagnostic pairs

CDT Procedure	Procedure Description	Diagnostic Code	Diagnostic Description	Number Performed	Adjudicated Accuracy Yes=1 N=0
9110	Emergency Palliative	Z1250	Caries +.5 Pulp (4)	65	1
9901	Chlorhexidine	Z1055	Moderate Chronic Periodontitis	60	1
9110	Emergency Palliative	Z1260	Fracture: Dentin (II)	47	1
9110	Emergency Palliative	Z1515	Irreversible Pulpitis	46	1
9110	Emergency Palliative	Z1215	Caries to the Pulp	41	1
9901	Chlorhexidine	Z1060	Advanced Chronic Periodontitis	22	1
9901	Chlorhexidine	Z1050	Slight Chronic Periodontitis	13	1
9640	Extra Fluoride (e.g., Control Rx)	Z1220	Recurrent Caries	11	1
9640	Extra Fluoride (e.g., Control Rx)	Z1130	Caries Risk High	233	0
9901	Chlorhexidine	Z1130	Caries Risk High	231	0
9640	Extra Fluoride (e.g., Control Rx)	Z1055	Moderate Chronic Periodontitis	37	0
9901	Chlorhexidine	Z1145	Caries Activity High	30	0
9640	Extra Fluoride (e.g., Control Rx)	Z1145	Caries Activity High	27	0
9110	Emergency Palliative	Z1000	PERIO	5	0
9110	Emergency Palliative	Z1200	CARIES	4	0

dentistry, with fine granularity, including the extent of disease, like caries. Many of the diagnostic terms were utilized. Those diagnostic terms not used may represent conditions not frequently treated in a dental school clinic or may indicate that some terms are incorrectly underused.

As this vocabulary was developed in the context of an academic dental center, the primary rationale for the development of the diagnostic descriptions was to reinforce the reasoning of why specific procedures were being performed. From an educational point of view, the faculty felt it was important to teach dental students to define at the treatment planning stage the working diagnosis and to make a definitive diagnosis at the time of completion of the procedure.

Utilization of the diagnostic codes and descriptions by students and faculty members were encouraged but not mandated. During implementation, students and faculty members readily learned how to attach a diagnosis to a procedure in the treatment plan. Students also confirmed the diagnosis when the procedure was completed, and the faculty member electronically approved the procedure-diagnosis pair in the EHR. This provided us with the ability to assess the validity of the utilization of the codes by assessing the appropriateness of the pairings.

Validation of the association of procedures and diagnostic descriptions was completed by three independent dental faculty observers. The inter-evaluator agreement was good, and when there was not perfect agreement among the three evaluators, adjudication occurred until consensus was achieved Some adjudications were relatively easy, as when providers chose a category of disease as a diagnosis (e.g., "caries," "periodontal") or when a pairing was clearly erroneous (e.g., a periodontal diagnosis associated with a restorative procedure). Some associations were not as straightforward, such as "periodontal health" diagnostic description paired with the "periodontal maintenance" procedure or, similarly, an "adult prophylaxis" procedure associated with "periodontal disease" diagnosis. It may have been that these associations were appropriate given the context; however, the faculty observers were conservative in their assessments, validating as accurate only clearly appropriate procedure-diagnosis pairings. This article reports accurate and valid pairings of diagnostic terms with specific treatment procedures. Given the results in Tables 2 through 9, many of the associations are intuitive by experienced clinicians practicing dentistry. Within the context of

a dental academic setting, the pairings are important findings for validation of diagnostic terms and associated treatment procedures, as treatment planned and performed by dental students, being supervised by faculty members.

Diagnostic procedures were excluded from consideration in this study, as they are procedures associated with deriving a diagnosis. For instance, a "comprehensive oral examination" is completed in order to determine a diagnosis and may appropriately result in multiple diagnoses. As a result, diagnoses associated with a diagnostic procedure were not readily validated using the procedure-diagnosis pairing. Therefore, we excluded examinations, radiographs, and other diagnostic procedures from our analysis. In many cases for diagnostic procedures, the most accurate diagnostic term would be "none" or "not applicable."

When diagnostic codes were entered, they were most often used appropriately, with a valid utilization rate of 76.7 percent. Since there is a long established history of faculty oversight and approval of procedures, the accuracy of the procedures provided in a well-controlled academic clinic environment is very good. In addition, since patients pay for the procedures and services provided, any inaccuracies would be corrected through the billing process (i.e., patient complaints). The accuracy of the diagnosis was not as high as anticipated, with a 23.3 percent error rate. The inaccuracies seen in this study we believe come from the newness of the use of the diagnostic codes by students, inexperience of the faculty in reviewing and approving diagnosis, and user interface issues in viewing the selected diagnostic terms at approval. Some of the inaccuracies cited are clearly errors, while some may be differences of professional opinion as to what treatment is appropriate for an individual patient. The diagnostic codes were only utilized 38.9 percent of the time. This low utilization rate is a reflection on the lack of attention to detail students and faculty members had in ensuring complete utilization of the electronic health record, given the fact that the field was not mandatory to complete, and indicates a general lack of understanding of why the use of a standardized vocabulary is important.

Future work will focus on improvements to the diagnostic terms and codes, as well as better integration of diagnostic code entry into the dental clinical workflow and is the basis for future work. This work has also been the impetus for COHRI to make further refinements and developments to the

diagnostic coding and description system.[12] COHRI, as part of the users group of dental institutions using the same EHR, has developed an "EZ codes," a further advancement of the diagnostic code and description system based on the Z codes. This "EZ" system is being implemented in a number of dental schools. As this set of diagnostic terms and codes develops and is used through COHRI in the academic setting, we anticipate future studies will be undertaken to map the terms with other systems, like ICD and SNOMED. Further analysis of the process of diagnostic term entry into the EHR, as well as the analysis of the invalid pairing of diagnosis and treatment procedures, may prove helpful in determining enhancements to the EHR system necessary to make the process of entry easier.

Conclusion

This study demonstrates successful development, implementation, and utilization of diagnostic codes and terms in an electronic health record. Fewer than 100 terms and codes were most often used in a predoctoral clinical program. Elective utilization of the diagnostic terms and codes was low, but the validity of the terms when used was high. Further improvements to the diagnostic terms and codes and the user interface will likely increase use of diagnostic terms and codes in dentistry.

Acknowledgments

REFERENCES

1. Shortliffe EH, Barnett GO. Biomedical data: their acquisition, storage, and use. In: Shortliffe EH, Cimino JJ, eds. Biomedical informatics computer applications in health care and biomedicine. New York: Springer, 2006:66–9.
2. Ledley RS, Lusted LB. Reasoning foundations of medical diagnosis: symbolic logic, probability, and value theory aid our understanding of how physicians reason. Science 1959;130(3366):9–21.
3. Adams R. Testimony to the Subcommittee on Standards and Security National Committee on Vital and Health Statistics on Dental Standards Issues. Washington, DC: National Association of Dental Plans, 2004.
4. Torres-Urquidy MH, Schleyer T. Evaluation of the systematized nomenclature of dentistry using case reports: preliminary results. AMIA Annu Symp Proc 2006:1124.
5. American Dental Association. Current dental terminology 2009–10. Chicago: American Dental Associaton, 2008.
6. Leake JL. Diagnostic codes in dentistry: definition, utility, and developments to date. J Can Dent Assoc 2002; 68(7):403–6.
7. Goldberg LJ, Ceusters W, Eisner J, Smith B. The significance of SNODENT. Stud Health Technol Inform 2005;116:737–42.
8. Leake JL, Main PA, Sabbah W. A system of diagnostic codes for dental health care. J Public Health Dent 1999; 59(3):162–70.
9. Schleyer TK, Thyvalikakath TP, Spallek H, Torres-Urquidy MH, Hernandez P, Yuhaniak J. Clinical computing in general dentistry. J Am Med Inform Assoc 2006;13(3): 344–52.
10. Stark PC, Kalenderian E, White JM, Walji MF, Stewart DC, Kimmes N, et al. Consortium for oral health-related informatics: improving dental research, education, and treatment. J Dent Educ 2010;74(10):1051–65.
11. Landis JR, Koch G. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
12. Kalenderian E, Ramoni RL, White JM, Schoonheim-Klein ME, Stark PC, Kimmes NS, et al. The development of a dental diagnostic terminology. J Dent Educ 2011;75(1): 68–76.