Tracking oral health in a standardized, evidence-based, prevention-focused dental care system

Joel M. White, DDS, MS[1]; Ryan G. Brandon, BS[2,3]; Joanna M. Mullins, RDH, BSDH, MHI[2]; Kristen L. Simmons, BSDH, RDH, MHA[2]; Aubri M. Kottek, MPH[1]; Elizabeth A. Mertz, PhD, MA[1]

1 Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, CA, USA
2 Willamette Dental Group and Skourtes Institute, Hillsboro, OR, USA
3 Independant Consultant, Maple Ridge, BC, Canada

Keywords
dentistry; dental caries; electronic health records; primary prevention; secondary prevention; dental informatics; value-based payment.

Correspondence
Joel M. White, Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, CA.
Tel.: 415 476 0918; Fax: 415 476 0585;
e-mail: joel.white@ucsf.edu. Joel M. White, Aubri M. Kottek, Elizabeth A. Mertz are with Department of Preventive and Restorative Dental Sciences, University of California. Ryan G. Brandon, Joanna M. Mullins, and Kristen L. Simmons are with Willamette Dental Group and Skourtes Institute.

Received: 6/12/2020; accepted 10/9/2020.

doi: 10.1111/jphd.12413

J Public Health Dent (2020)

Abstract

Objectives: Learning health-care systems are foundational for measuring and achieving value in oral health care. This article describes the components of a preventive dental care program and the quality of care in a large dental accountable care organization.

Methods: A retrospective study design describes and evaluates the cross-sectional measures of process of care (PoC), appropriateness of care (AoC), and outcomes of care (OoC) extracted from the electronic health record (EHR), between 2014 and 2019. Annual and composite measures are derived from EHR-based clinical decision support for risk determination, diagnostic and treatment terminology, and decayed-missing-filled-teeth (DMFT) measures.

Results: Annually, 253,515 ± 27,850 patients were cared for with 618,084 ± 80,559 visits, 209,366 ± 22,300 exams, and 2,072,844 ± 300,363 clinical procedures. PoC metrics included provider adherence (98.3 percent) in completing caries risk assessments and patient receipt (96.9 percent) of a proactive dental care plan. AoC metrics included patients receiving prevention according to the risk-based protocol. The percent of patients at risk for caries receiving fluoride varnish was 95.4 ± 0.4 percent. OoC metrics included untreated decay and new decay. The 6-year average prevalence of untreated decay was 11.3 ± 0.3 percent, and average incidence of new decay was 13.6 ± 0.5 percent, increasing with risk level: low = 7.5 percent, medium = 18.8 percent, high = 29.4 percent, and extreme = 28.1 percent.

Conclusions: The preventive dental care system demonstrates excellent provider adherence to the evidence-based prevention protocol, with measurably better dental outcomes by patient risk compared to national estimates. These achievements are enabled by a value-centric, accountable model of care and incentivized by a compensation model aligned with performance measures.

Introduction

Dental caries (tooth decay) is the most prevalent chronic disease in the United States, affecting children and adults. *Healthy People 2020* (HP2020) goals for children and adults include reducing untreated decay. Sixteen percent of children have untreated dental decay. Experience with tooth decay varies by age and dentition: 36 percent of children ages 2–8 years with primary teeth, 21 percent among children ages 6–11 with both primary and permanent teeth, rising to 58 percent of children ages 12–19 with permanent teeth.[1] In adults, 91 percent of people ages 20–64 have experienced tooth decay, with 27 percent of this population having untreated tooth decay.[1] Oral care is among the greatest unmet health needs in the United States.[2] While oral health is universally accepted as a critical component of overall health and well-being, 30 percent of the US population lacks dental insurance coverage, resulting in the US Surgeon General declaring dental caries a "silent

epidemic."[3] The economic cost to society of the oral disease burden is substantial, with annual US dental expenditures at $96 billion in 2015.[4]

Value-based reforms to the delivery and payment of dental care have been touted as critical to making progress in improving access to high-quality care and reducing the overall burden of oral disease. "Value-based care is a person/patient centered approach to health care delivery designed to improve health outcomes and lower the cost of care. Value-based payers reimburse providers based on the quality of care instead of the volume of care."[5] While value-based payment models have been conceptualized in dentistry,[6] there are few empirical studies that demonstrate this approach. In part, this is because the traditional surgical approach to treatment in dentistry, along with the historical small business, fee-for-service delivery model, leaves providers ill-equipped to measure or manage population level outcomes.[7] Medicare and Medicaid have pioneered contracting in new managed care and value-based models,[8] but traditional Medicare does not cover dental care, and most dentists do not accept Medicaid.[9] However, as dental care evolves and consolidates into larger delivery systems,[10] we see both infrastructure and contracting changes that enable value-based approaches. Large organizations are able to adopt the necessary tools such as health information technology (HIT), electronic health records (EHRs), dental diagnostic terminology, and clinical decision support (CDS) that enable a population, prevention-based, chronic disease-management approach.

By integrating HIT into patient care, dental practices can enable the implementation of standardized, evidence-based guidelines endorsed by the American Dental Association (ADA) and create new opportunities for research and quality improvement both at the individual patient and population levels.[11] Embracing HIT has occurred simultaneously with growing evidence that supports philosophically shifting dental caries treatment away from conventional surgical dentistry in favor of medical management with an emphasis on disease treatment, prevention and personalized care.[12] This is achieved by using existing, easy-to-implement caries risk assessment (CRA) tools, embedded within the EHR, that have demonstrated high predictive validity for future caries.[13, 14] Randomized controlled trials that used risk prediction to target non-surgical therapies to high-risk patients have demonstrated reduced caries risk[15] and caries incidence,[16] as well as cost-effectiveness.[17] When providers and patients engage in risk-based preventive care, patients experience less tooth decay and require fewer surgical treatments.[14] These approaches are the bedrock of bringing value to oral health care.

Willamette Dental Group (WDG), a large dental accountable care organization, is an example of a learning health-care system driving value in oral health care, aiming to align science, informatics, incentives, and culture through a continuous quality improvement process moving toward innovation. WDG's mission is "to deliver proactive patient care through a partnership with our patients to stop the disease-repair cycle by means of evidence-based methods of prevention and treatment." WDG is a privately owned organization consisting of a large, multispecialty group practice and integrated dental insurance company delivering care through a full-risk capitation model. With 50 dental offices located throughout Washington (WA), Oregon (OR), and Idaho (ID), the company employs 155 general dentists, 52 specialists, 235 hygienists, 222 care advocates, and 549 dental assistants, among it's over 1,500 employees. Their caries prevention program includes a robust prevention focus, self-management support, CDS, efficient and consistent delivery system design, clinical information systems, and quality of care measures derived from system-wide EHR/HIT. This has been made possible through a $10 M investment in HIT, along with high levels of engagement and participation by leadership from the executive to clinic levels and fully integrating data capacity and roles into every level of the organizational system. Their model of care embraces the tenets of a learning healthcare system and the quadruple aim (better health, better care, lower cost, and an engaged workforce) by utilizing the EHR to standardize clinical workflows and robust data analytics for continual quality improvement.[18-22]

This study describes the implementation of WDG's evidence-based dental caries prevention and management program and describes its performance measures over the first 6 years using EHR measures derived from dental diagnostic terms and a newly validated clinical outcome measure.[13, 23] The study aim is to utilize HIT to track and report retrospective, cross-sectional, annual oral health measures in a large health-care system that has implemented current best practices to improve oral health care quality and effectiveness, and examine the value of this approach in managing caries in the dental clinic setting.

Methods

This work was conducted under approval of the UCSF Institutional Review Board.

Caries preventive care program

Using the current best evidence and practice guidelines, based on caries risk,[13, 16, 24-30] WDG created the Caries Preventive Care Program Clinical Guidelines (Table 1 and Supporting Information for evidence SI). WDG's caries preventive care program is a treatment philosophy that is

Table 1 Willamette Dental Group Caries Preventive Care Program Clinical Guidelines

Caries risk level	In-office preventive care	Home care guidance	Home care prevention products	Next caries risk assessment	Next comprehensive exam
Low	Sealants for teeth with pits and fissures at risk for breakdown	OHI to reduce plaque and diet evaluation to reduce sugar	OTC toothpaste OTC mouthwash	@ next comprehensive exam (12 months)	@ 12 months BW radiographs every 24–36 months
Moderate	Above + FV	OHI to reduce plaque and diet evaluation to reduce sugar	Rx toothpaste or OTC toothpaste + OTC mouthwash	@ 6 months FV for enamel lesions, BWs if monitoring interproximal lesions, re-evaluate risk	@ 12 months FV, BWs if monitoring interproximal lesions
High and Extreme	Above + minimally invasive restorations, SDF on deep cavitated dentin lesions	OHI to reduce plaque and diet evaluation to reduce sugar	Rx toothpaste, CHX regimen, acid reduction strategy if has dry mouth	@ 3 or 6 months Above + re-evaluate risk monitoring interproximal lesions	@ 6 or 12 months FV or SDF, BW radiographs

BW, bitewing radiographs; CHX, chlorhexidine/anti-microbial rinse; FV, fluoride varnish; OHI, oral hygiene instruction (brushing/flossing); OTC, over-the-counter anti-cavity fluoride products; Rx, prescription 1.1% fluoride toothpaste; SDF, silver diamine fluoride.

standardized, diagnosis-driven, risk-based, and evidence-based with CDS in a preventive care model. The program combines prevention, minimally invasive intervention, and patient engagement to reduce caries risk status and improve patient outcomes. Patients receive oral hygiene instructions to reduce plaque, diet management to reduce sugars and fermentable carbohydrates, fluoride supplements for developing teeth in non-fluoridated areas, toothpaste (over the counter or prescription) and anti-cavity rinses, antimicrobial rinses, in-office fluoride varnish, sealants, and standardized recall and radiographs according to caries risk level and age (less than 6, and 6 and older).

To implement the program in 2013 over a 6-months period, WDG trained all employees involved in clinical care with formative assessments consisting of written and hands-on case-based examinations. WDG launched the program company-wide in the fall of 2013, with a 3-months roll-in period. Every patient receiving a comprehensive or periodic oral exam completes a demographic and standardized health and dental history form recorded in the EHR. A standardized caries risk determination is achieved by consideration of disease indicators, risk factors and protective factors, calculated in an integrated CDS algorithm in the EHR.[13, 31, 32] The clinicians select dental diagnoses before selecting a procedure code using a validated set of standardized diagnostic terminology.[13, 33] CDS in the EHR suggests/flags procedures that may be performed to treat the diagnosis.

The entire team has access to the system-wide EHR (axiUm, Exan, Coquitlam, BC, Canada). The team is trained to document health history, risk status, diagnosis, and treatment plan in the EHR, which automatically populates a personalized Proactive Dental Care Plan (PDCP) that identifies the patient's disease risk using a visual scale of green (low) to red (high) and lists at-home and in-office preventive actions to reduce risk and decay. The PDCP is used to foster patient engagement and to counsel and motivate patients toward specific caries preventive interventions based on caries risk, such as in-office applications of fluoride varnish, over-the-counter anti-cavity products, prescription antimicrobial rinses, or prescription high fluoride toothpaste, and diet modifications. High-risk patients are scheduled to return for a CRA every 3–6 months for patient education, motivation, and assessment. Trained office staff known as Care Advocates coordinate managing all patients, focusing additional care and interventions for high-risk patients using a structured form in the EHR for follow-up.

Data metrics and analytics

The WDG caries prevention program is supported by performance data analytics available at the patient, office, regional, and organizational levels. Provider teams have multiple measures at the individual level readily available and displayed in the EHR. Measures to describe the patient population are *Members enrolled*, *Visits*, *and Patients with an exam*. The care measures we include in this study are for Process of Care (PoC), Appropriateness of Care (AoC), and Outcomes of Care (OoC). PoCs are derived from the robust documentation of patient information, including medical and dental history, vital signs, extra/intraoral examination, self-reported oral hygiene/nutrition, findings

Table 2 Description of Patient Population of Willamette Dental Group Caries Preventive Care Program From 2014 Through 2019

	Program year						
Patient population	2014	2015	2016	2017	2018	2019	Average (SD)
Members enrolled	397,146	403,224	425,221	445,315	476,410	502,471	441,631 (41,588)
Children members (<18 years)	108,674	104,533	106,023	109,172	114,043	118,167	110,102 (5,121)
Adult members (18–55 years)	225,283	232,633	248,177	260,804	280,996	297,149	257,507 (27,850)
Senior members (>55 years)	63,187	66,057	71,020	75,338	81,371	87,153	74,021 (9,143)
Patients with a visit	221,471	229,543	242,179	260,485	275,976	291,434	253,515 (27,280)
Visits	530,137	550,003	580,489	624,649	687,871	735,354	618,084 (80,559)
Clinical procedures	1,790,452	1,818,520	1,891,939	2,065,406	2,361,130	2,509,618	2,072,844 (300,363)
Patients with exam	183,779	190,610	198,754	214,730	226,784	241,540	209,366 (22,300)
Comprehensive oral exams (D0150)	52,548	50,934	55,230	59,484	63,532	63,476	57,534 (5,456)
Periodic oral exams (D0120)	128,048	136,154	140,078	151,159	158,887	173,362	147,948 (16,570)
Oral evaluations (<3 years old) (D0145)	3,973	4,239	4,202	4,876	5,290	5,725	4,718 (695)

Table 3 Process of Care (PoC), Appropriateness of Care (AoC) and Outcomes of Care (OoC) Measures of Willamette Dental Group Caries Preventive Care Program From 2014 Through 2019

	Program year						
	2014	2015	2016	2017	2018	2019	Average (SD)
Process of care (PoC)							
Percent of patients with CRA	98.4%	98.6%	98.5%	98.3%	98.2%	98.1%	98.3% (0.2)
Proactive dental care plan	96.9%	97.2%	97.2%	96.8%	96.8%	96.7%	96.9% (0.2)
Appropriateness of care (AoC)							
Radiographs planned interval	94.7%	95.2%	95.4%	95.0%	92.6%	94.9%	94.6% (1.0)
Radiographs taken (on interval)	78.3%	77.1%	78.1%	78.3%	74.2%	74.9%	76.8% (1.7)
Fluoride varnish (elevated risk)	94.8%	95.6%	95.3%	95.1%	95.6%	96.1%	95.4% (0.4)
Silver diamine fluoride application*	n/a	n/a	0.9%	12.5%	23.9%	18.6%	14.0% (9.8)
Outcome of care (OoC)							
Patients with untreated decay at end of year	21,071	20,748	21,856	23,366	25,454	27,989	23,414 (2,833)
Patients with new decay	11,008	15,774	17,331	17,993	19,842	23,079	17,505 (4,050)

* SDF,Silver diamine fluoride use was added to the program in 2016.

of demineralization and decay, and conditions, including existing restorations. The measures include patients with a CRA, provider-selected caries risk alignment to CDS, and patients receiving their PDCP. AoCs include radiographic recall interval, radiograph planned/taken, fluoride varnish, and silver diamine fluoride (SDF) applications for cavitated carious lesions in dentin, and procedures in phase. OoCs are derived from patients with an exam and measured with a validated tool that calculates the recognized standard caries index outcome measures; number of decayed, missing, or filled permanent teeth and tooth surfaces (DMFT/S for permanent teeth and dmft/s for primary teeth).[23] WDG adapted these caries indices to measure untreated decay and new decay, the OoC measures. (full definitions of measures are available in online Supporting Information SI.)

For this retrospective study, all data were extracted directly from the EHR's relational database management system, using standard query language (SQL) statements, from January 1, 2014 through December 31, 2019. Data were analyzed annually, calculating annual percentages, averages, and standard deviations.

Results

Patient population

Between 2014 and 2019, there were 1,521,088 patients seen, 3,708,503 visits, and 12,437,065 clinical procedures performed at WDG. The average number of members enrolled in WDG per year was 441,631 ± 41,588. Among all members, children (less than 18 years of age) were 25 ± 1.4 percent, adults (ages 18–55) were 58.2 ± 0.9 percent and seniors (greater than 55 years of age) were 16.7 ± 0.5 percent. Of the patients who had a visit, 55.6 percent resided in OR, 34.8 percent resided in WA and 9.6 percent resided in ID, while 44.1 percent were

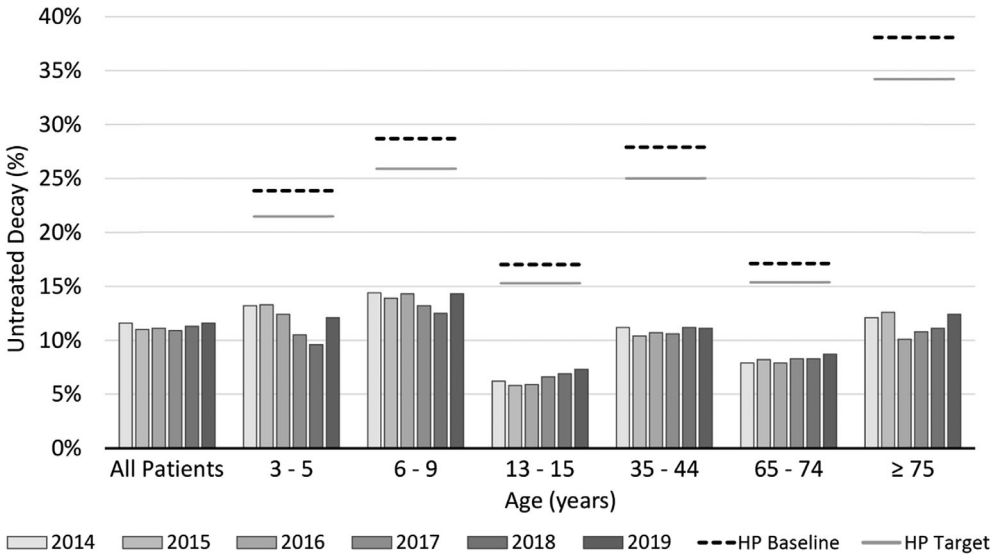

Figure 1 Prevalence of untreated decay as a function of age – outcome of care measures (OoC) of Willamette Dental group caries preventive care program from 2014 through 2019, compared to healthy people 2020 (HP 2020) baseline and target measures.

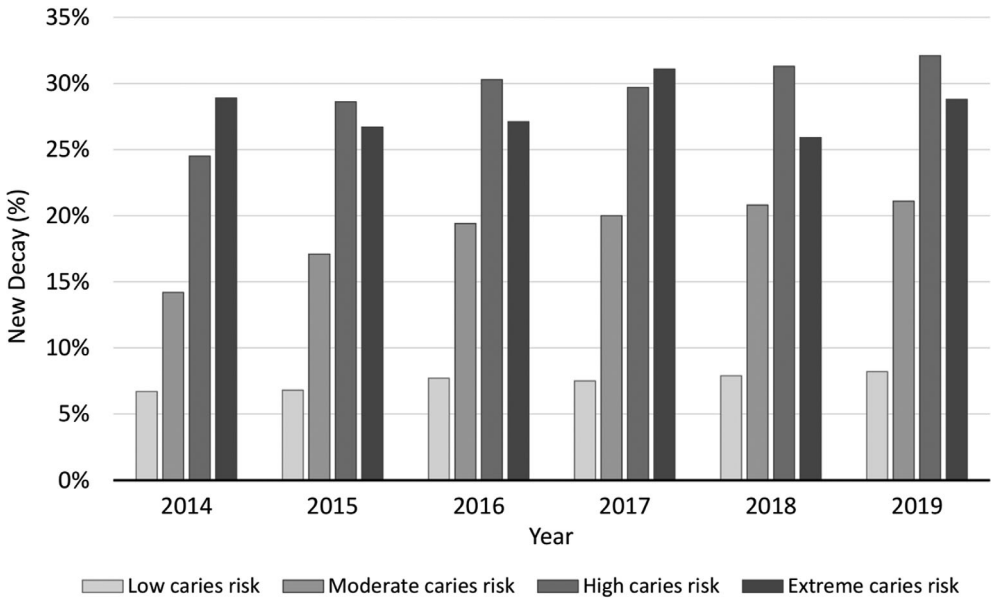

Figure 2 Incidence of new decay as a function of caries risk — outcome of care measures (OoC) of Willamette Dental group caries preventive care program from 2014 through 2019.

male and 55.9 percent were female. The number of patients with a visit increased from 221,471 to 291,434. The number of patient visits increased from 530,137 to 735,354, with an average of 2.4 visits per patient per year. Procedures increased from 1,790,452 to 2,509,618, with an average of 3.4 clinical procedures/visit. In total, 1,256,197 patient examinations were completed, with 345,204 comprehensive exams, 887,688 periodic oral exams, and 28,305 oral evaluations for patients less than 3 years old. In each year, 82.6 ± 0.4 percent of patients seen had an examination within the year (D0150, D0120 or D0145), which increased from 183,779 to 241,540. Of the patients seen annually, 22.7 ± 0.6 percent were seen for new patient visits (D0150), 58.4 ± 0.7 percent were periodic oral examinations (D0120), and 2.3 ± 0.1 percent were oral evaluations for patients less than 3 years old (D0145) (Table 2).

Process of Care

PoC measures of the preventive care program were consistently high throughout 6-year period (Table 3 and online Supporting Information SI). A total of 1,235,254 CRAs were completed, with an annual average of 205,876 ± 21,590 patients receiving a CRA at their exam visit (98.3 ± 0.2 percent). The caries risk of the patients receiving a CRA was 62.6 ± 2.8 percent low risk, 16.6 ± 2.3 percent moderate risk, 20.4 ± 1.3 percent high risk, and 0.4 ± 0.2 percent extreme risk. The provider-selected caries risk was aligned with the CRA CDS algorithm 90.2 ± 1.3 percent of the time. Provider alignment with CRA CDS for low risk was 93.6 ± 0.5 percent, moderate risk was 74.5 ± 4.5 percent, high risk was 92.6 ± 0.5 percent, and extreme risk was 87.4 ± 3.0 percent. Patients received a PDCP 96.9 ± 0.2 percent of the time.

Appropriateness of Care

AoC measures of the preventive care program were also consistently high throughout 6-year period (Table 3). Providers planned recall radiographs according to the evidence-based protocol intervals on average 94.6 ± 1.0 percent of the time. Radiographs were taken at shorter intervals 76.8 ± 1.7 percent of the time. Dental procedures were completed in the appropriate phase of care on average 99.6 ± 0.04 percent of the time. Patients at elevated risk (moderate/high/extreme) received fluoride varnish on average 95.4 ± 0.4 percent of the time. SDF application to arrest deep cavitated caries in dentin was incorporated into the preventive care program in 2016. The use of SDF in high/extreme caries risk patients increased beginning with its introduction, 0.9 percent in 2016, 12.5 percent in 2017, 23.9 percent in 2018, and 18.6 percent in 2019.

Outcomes of Care

On average 207,828 ± 23,028 patients received an annual examination, of which 23,414 ± 2,833 patients had untreated decay at the end of the year. The percent of patients with untreated decay was on average 11.3 ± 0.3 percent (Table 3 and online Supporting Information SI). Percent of children ages 3–5 with untreated decay on primary teeth was on average 11.8 ± 1.5 percent. Percent of children ages 6–9 years old with untreated decay on primary or permanent teeth was on average 13.8 ± 0.8 percent. Percent of adolescents ages 13–15 years with untreated decay was on average 6.4 ± 0.6 percent. Percent of adults ages 25–44 years with untreated coronal caries averaged 10.9 ± 0.4 percent while those ages 65–74 years averaged 8.2 ± 0.3 percent, and the percent of adults ages 75 and older with untreated coronal or root caries averaged 11.5 ± 1.0 percent. All of the WDG measures were lower than their comparable HP2020 baseline and target measures (Figure 1). On average, 128,102 ± 26,813 patients had a qualifying prior exam, with an average of 17,505 ± 4,050 patients having new decay annually (13.6 ± 0.5 percent). Of the patients who had a CRA of low caries risk, 7.5 ± 0.6 percent had new decay, while 18.8 ± 2.7 percent of moderate risk, 29.4 ± 2.7 percent of high risk and 28.1 ± 1.9 percent of extreme risk patients having new decay (Figure 2).

Discussion

This article describes the first 6 years of measurable performance of a model of dental care that is evidence-based, standardized, diagnosis-driven, risk-based, clinical decision supported, patient-centered, preventive and minimally invasive, deployed in a large dental accountable care organization. The system-wide EHR enables standardized care and provides the data for performance analytics to drive patient care, provider behavior, and quality improvement throughout the enterprise.[22] The value-based approach to care advances the quadruple aim of better health, better care, lower cost and an engaged workforce..[18-20]

The goal of the program is to prevent, arrest, remove, and restore decay. At WDG, it is considered a failure of prevention when a dentist must intervene surgically. The system allows the practitioners easy access to data and decision support that allows them to adhere to best practices that underpin their clinical approach. In the course of this retrospective study and through results of satisfaction surveys, we found that the program was well-received by patients and providers.[34, 35] Adherence to PoC and AoC measures is excellent. Patients receive appropriate prevention. Restorative care provided is within the appropriate phase, addressing patients' emergency needs first, then disease removal and restoration before tooth reconstruction and replacement, all with ongoing prevention and recall.

WDG is a learning healthcare system that utilizes a robust HIT system to drive better oral health outcomes at the patient, provider, office, region, and company-wide levels.[36] The program uses standardized care following guidelines and best practices with CDS within a robust EHR. This allows the organization to maintain control over quality improvement as the organization grows and new evidence for practice is developed. The number of WDG offices stayed steady over the study period. As the number of members increased, there was an increase in the number of patient exam visits from 183,779 to 241,540. WDG increased the number of providers during the study period to accommodate the growth in membership. The percent of patients with a risk assessment at each

exam stayed steady at over 98 percent attesting to the robust IT system and culture to support this practice over time.

The comprehensive use of CRA drives value by concentrating resources where they are most needed to positively influence population health, as our data on the connection between caries risk level and new decay clearly show. In this study, large-scale implementation of caries management by risk assessment (CAMBRA) enabled the proportion of patients with new decay to be consistently lower than previous work validating CRA[13, 14] and in a randomized prospective clinical trial.[16] The prevalence of untreated caries on average and for each age group were lower than HP2020 baseline and target goals,[37] indicating the WDG caries prevention program has positive program impact at the population level.

WDG drives this level of performance by utilizing data analytics in their value-based delivery model with goals and measures at the provider, office, region, and company level that are incorporated in the "pay for value" compensation model. Factors considered for compensation/incentives for the dentists are a combination of patient mix, schedule effectiveness score, quality improvement score (PoC, AoC, and OoC measures), and customer service. The compensation model emphasizes a preventive care philosophy, incentivizing performance, value, and outcomes (e.g., reduction in untreated caries and new decay).

PoC measures, as quality assurance measures, allows for the capture of the essential elements of patient care quality. Adherence to PoC measures allows for the determination of AoC measures, which ensure patients receive appropriate care based on caries risk, including prevention and treatment of dental decay. Adherence to both PoC and AoC measures is critical in tracking and achieving outcomes, whereas OoC measures allow for evaluating the preventive care program's success in removing and restoring decay (i.e., untreated decay) and prevention (i.e., new decay). All three sets of measures work together to help the organization achieve appropriate and timely care and provide data for continual quality improvement. An excellent example of this interrelatedness is the summative PDCP. PoC, AoC, and OoC measures provide data elements that populate the patients' PDCPs. Patients receive their PDCP, a PoC measure itself, that includes their caries risk (PoC), at home prevention and in-office prevention and treatment recommendations (e.g., prescription fluoride toothpaste and fluoride varnish-AoCs), and their oral health status (e.g., untreated decay and new decay-OoCs).

This model of care is different than traditional fee for service dental practice and dental service organizations where the financial incentives are procedure based. Similar to physicians' practice consolidation, large group practices are now the largest growth sector, reshaping the future of dentistry.[10, 38] WDG is similar to other large group dental practices, such as HealthPartners and Kaiser Permanente Northwest, enrolled in the National Dental Practice-Based Research Network, which have been shown to have many commonalities with dentists at large in the United States.[39] Yet, each WDG office is functionally similar to traditional dental practices in the community. WDG dentists are also representative of the profession's future diversity. Compared to other dentists in OR, WA, and ID, WDG dentists are more commonly female (35.9 percent versus 26.2 percent), non-white (47.5 percent versus 22.3 percent), and younger (29.5 percent ages 21–34 versus 16.7 percent). Similarly, WDG's patient demographics are comparable to overall population demographics in ID, OR, and WA (50 percent female, 26 percent non-white, 19 percent Medicaid beneficiaries)[40, 41] and dental attenders across the United States (58 percent female, 30 percent non-white, 29 percent Medicaid beneficiaries).[42]

This study describes the organization, measurement, and clinical implications of widely incorporating a risk-based caries prevention program for a large population with long-term follow-up. This article provides rich context for ongoing studies focused on the real-world effectiveness of clinical preventive approaches to patient and population health management in dentistry. By utilizing the robust EHR data, we will be able to further study the model of care longitudinally, through the construction of matched groups for health disparities research in order to draw causal inferences.[43] The economic aspects of this model of care can also be assessed to determine the cost-effectiveness (e.g., the preventive costs of a cavity) and cost–benefit (e.g., patients' willingness to pay for prevention verses restoration). In addition, the observational research on systems performance is ripe for translation, replication, and dissemination.

With the challenges of COVID-19, dentistry is in the process of transforming and adapting its care delivery. To protect patients, providers and the public, dentistry is prioritizing emergent and urgent care over routine dental care, until testing is more widely available. Due to the hazards of aerosols, routine restorative procedures and ultrasonics require additional safety requirements. Use of SDF to arrest deep cavitated carious lesions in dentin, atraumatic restorative technique and glass ionomer restorations as minimally invasive dentistry lowers the risk of COVID-19 exposure to patients, providers and the public. Learning health-care systems will adapt quickly and meet the challenges posed by COVID-19. The model of care reported in this article is very well suited toward changes required by COVID-19 with their focus on prevention and a minimally invasive approach.

Acknowledgments

Research reported in this article was supported by the National Institute on Minority Health and Health Disparities of the National Institutes of Health under award number R01MD013719: Reducing Oral Health Disparities in Children: Assessing the Multilevel Impact of a Standardized Preventive Dental Care System. Support was also provided by the National Institute of Dental and Craniofacial Research under award R01DE024166: Implementing Dental Quality Measures in Practice. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors are grateful to Dr. Eugene Skourtes, the executive leadership, and the entire Willamette Dental Group organization, without which this study would not have been possible. The authors acknowledge the excellent background work of Dr. Larry Jenson made possible by the financial support provided by the Khandros Family Foundation. The authors acknowledge Shaeema Siddiqui for her contribution to reference management that was supported by the Raymond L. and Mary V. Bertolotti Distinguished Professorship in Restorative Dentistry.

References

1. Dye BA, Thornton-Evans G, Li X, Iafolla TJ. *Dental caries and tooth loss in adults in the United States, 2011–2012*. Hyattsville, MD: National Center for Health Statistics; 2015.
2. Institute of Medicine. *Improving access to Oral health care for vulnerable and underserved populations*. Washington, DC: National Academies Press; 2011.
3. U.S. Department of Health and Human Services. Oral Health in America. *A report of the surgeon general*. Rockville, MD: U.S. Department of Health and Human Services; 2000.
4. Manski RJ, Rohde F. *Research Findings No 38: Dental services: use, expenses, source of payment, coverage and procedure type, 1996–2015*. Rockville, MD: Agency for Healthcare Research and Quality; 2017.
5. Apostolon D. Value-based care: DentaQuest partnership for oral health advancement; 2018 Available from: https://www.dentaquestpartnership.org/about/keys-to-success/value-based-care
6. Riley W, Doherty M, Love K. A framework for oral health care value-based payment approaches. *J Am Dent Assoc*. 2019;**150**(3):178–85.
7. Rubin MS, Edelstein BL. Perspectives on evolving dental care payment and delivery models. *J Am Dent Assoc*. 2016; **147**(1):50–6.
8. Value-Based Programs: Centers for Medicare & Medicaid Services. 2020. Available from: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/Value-Based-Programs/Value-Based-Programs.
9. American Dental Association HPI. *Dentist participation in Medicaid or CHIP*. Chicago, IL: American Dental Association; 2016. Available from: https://www.ada.org/~/media/ADA/Science%20and%20Research/HPI/Files/HPIGraphic_0318_1.pdf?la=en.
10. Health Policy Institute. *How big are dental service organizations?* Chicago, IL: American Dental Association; 2017.
11. Liu K, Acharya A, Alai S, Schleyer TK. Using electronic dental record data for research: a data-mapping study. *J Dent Res*. 2013;**92**(7):90S–6S.
12. Fontana M, Young DA, Wolff MS. Evidence-based caries, risk assessment, and treatment. *Dent Clin N Am*. 2009;**53** (1):149–61.
13. Domejean S, White JM, Featherstone JD. Validation of the CDA CAMBRA caries risk assessment--a six-year retrospective study. *J Calif Dent Assoc*. 2011;**39**(10):709–15.
14. Chaffee BW, Cheng J, Featherstone JD. Baseline caries risk assessment as a predictor of caries incidence. *J Dent*. 2015; **43**(5):518–24.
15. Rechmann P, Chaffee BW, Rechmann BMT, Featherstone JDB. Changes in caries risk in a practice-based randomized controlled trial. *Adv Dent Res*. 2018;**29**(1): 15–23.
16. Featherstone JD, White JM, Hoover CI, Rapozo-Hilo M, Weintraub JA, Wilson RS et al. A randomized clinical trial of anticaries therapies targeted according to risk assessment (caries management by risk assessment). *Caries Res*. 2012; **46**(2):118–29.
17. Warren E, Pollicino C, Curtis B, Evans W, Sbaraini A, Schwarz E. Modeling the long-term cost-effectiveness of the caries management system in an Australian population. *Value Health*. 2010;**13**(6):750–60.
18. Institute of Medicine (US) Roundtable on Evidence-Based Medicine. In: Olsen L, Aisner D, JM MG, editors*The learning healthcare system: workshop summary*. Washington, DC: The National Academies Press; 2007 374 p.
19. Institute of Medicine. *Best care at lower cost: the path to continuously learning health Care in America*. Washington, DC: National Academy of Sciences; 2012.
20. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. *Health affairs (Project Hope)*. 2008;**27** (3):759–69.
21. Bodenheimer T, Sinsky C. From triple to quadruple aim: care of the patient requires care of the provider. *Ann Fam Med*. 2014;**12**(6):573–6.
22. Finkelstein J, Zhang F, Levitin SA, Cappelli D. Using big data to promote precision oral health in the context of a learning healthcare system. *J Public Health Dent*. 2020; **80**:S43–S58.
23. White JM, Mertz EA, Mullins JM, Even JB, Guy T, Blaga E et al. Developing and testing electronic health record-derived caries indices. *Caries Res*. 2019;**6**(53): 650–8.

24. Chaffee BW, Cheng J, Featherstone JD. Baseline caries risk assessment and anti-caries therapy predict caries incidence. *J Dent Res*. 2014;**93**:190.
25. Featherstone JD, Domejean-Orliaguet S, Jenson L, Wolff M, Young DA. Caries risk assessment in practice for age 6 through adult. *J Calif Dent Assoc*. 2007;**35**(10):703–7.
26. Ramos-Gomez FJ, Crall J, Gansky SA, Slayton RL, Featherstone JD. Caries risk assessment appropriate for the age 1 visit (infants and toddlers). *J Calif Dent Assoc*. 2007; **35**(10):687–702.
27. Weintraub JA, Ramos-Gomez F, Jue B, Shain S, Hoover CI, Featherstone JD et al. Fluoride varnish efficacy in preventing early childhood caries. *J Dent Res*. 2006;**85**(2): 172–6.
28. Young DA, Featherstone JD, Roth JR, Anderson M, Autio-Gold J, Christensen GJ, Fontana M, Kutsch VK, Peters MC, Simonsen RJ, Wolff MS. Caries management by risk assessment: implementation guidelines. *J Calif Dent Assoc*. 2007;**35**(11):799–805.
29. Jenson L, Budenz AW, Featherstone JD, Ramos-Gomez FJ, Spolsky VW, Young DA. Clinical protocols for caries management by risk assessment. *J Calif Dent Assoc*. 2007;**35** (10):714–23.
30. Ismail AI, Tellez M, Pitts NB, Ekstrand KR, Ricketts D, Longbottom C, Eggertsson H, Deery C, Fisher J, Young DA, Featherstone JDB, Evans W, Zeller GG, Zero D, Martignon S, Fontana M, Zandona A. Caries management pathways preserve dental tissues and promote oral health. *Community Dent Oral Epidemiol*. 2013;**41**(1):e12–40.
31. Walsh CJ, Gansky SA, Vaderhobli RM, Fontana M, Rechmann P, White JM. Usability testing of clinical decision support caries risk assessment tools. *J Dent Res*. 2015;**94**(A):1080.
32. Domejean S, Leger S, Rechmann P, White JM, Featherstone JD. How do dental students determine patients' caries risk level using the caries management by risk assessment (CAMBRA) system? *J Dent Educ*. 2015;**79** (3):278–85.
33. Yansane A, Tokede O, White J, Etolue J, McClellan L, Walji M, Obadan-Udoh E, Kalenderian E. Utilization and validity of the dental diagnostic system over time in academic and private practice. *JDR Clin Trans Res*. 2019;**4** (2):143–50.
34. Mertz E, Bolarinwa O, Wides C, Gregorich S, Simmons K, Vaderhobli R, White J. Provider attitudes toward the implementation of clinical decision support tools in Dental practice. *J Evid Based Dent Pract*. 2015;**15**(4):152–63.
35. Mertz E, Wides C, White J. Clinician attitudes, skills, motivations and experience following the implementation of clinical decision support tools in a large dental practice. *J Evid Based Dent Pract*. 2017;**17**(1):1–12.
36. Simmons K, Gibson S, White JM. Drivers advancing oral health in a large group dental practice organization. *J Evid Based Dent Pract*. 2016;**16**:104–12.
37. U.S. Department of Health and Human Services. *Healthy People 2020: Oral Health*. Washington, DC: Office of Disease Prevention and Health Promotion; 2013–2014 Available from: https://www.healthypeople.gov/2020/topics-objectives/topic/oral-health.
38. Health Policy Institute. *How many dentists are in solo practice?* Chicago, IL: American Dental Association; 2018.
39. Makhija SK, Gilbert GH, Rindal DB, Benjamin P, Richman JS, Pihlstrom DJ. Dentists in practice-based research networks have much in common with dentists at large: evidence from "the Dental PBRN". *Gen Dent*. 2009;**57** (3):270–5.
40. Kaiser Family Foundation. State Health Facts: Medicaid Coverage Rates for the Nonelderly by Age, 2016: Kaiser Commission on Medicaid and the Uninsured; 2018. Available from: https://www.kff.org/medicaid/state-indicator/rate-by-age-3/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D
41. U.S. Census Bureau. *American FactFinder: Community Facts: 2017 American Community Survey*. Washington, DC: Department of Commerce; 2018 Available from: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml.
42. Christian B, Chattopadhyay A, Kingman A, Boroumand S, Adams A, Garcia I. Oral health care services utilisation in the adult US population: medical expenditure panel survey 2006. *Commun Dent Health*. 2013;**30**(3):161–7.
43. Cheng J, Gregorich SE, Gansky SA, Fisher-Owens SA, Kottek AM, White JM, Mertz EA. Constructing matched groups in dental observational health disparity studies for causal effects. *JDR Clin Trans Res*. 2020;**5**(1):82–91.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1: Definitions of Measures.
Appendix S2: Evidence Base for the Clinical Interventions of the WDG Caries Management Program..
Appendix S3: Supplemental online materials PoC and OoC Tables.

How to cite this article: White JM, Brandon RG, Mullins JM, Simmons KL, Kottek AM, Mertz EA. Tracking oral health in a standardized, evidence-based, prevention-focused dental care system. *J Public Health Dent*. 2020;1–9. https://doi.org/10.1111/jphd.12413

