The pediatric dental workforce in 2016 and beyond

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Supplemental material is available online.

ABSTRACT

Background. Childhood caries is a major oral and general health problem, particularly in certain populations. In this study, the authors aimed to evaluate the adequacy of the supply of pediatric dentists.

Methods. The authors collected baseline practice information from 2,546 pediatric dentists through an online survey (39.1% response rate) in 2017. The authors used a workforce simulation model by using data from the survey and other sources to produce estimates under several scenarios to anticipate future supply and demand for pediatric dentists.

Results. If production of new pediatric dentists and use and delivery of oral health care continue at current rates, the pediatric dentist supply will increase by 4,030 full-time equivalent (FTE) dentists by 2030, whereas demand will increase by 140 FTE dentists by 2030. Supply growth was higher under hypothetical scenarios with an increased number of graduates (4,690 FTEs) and delayed retirement (4,320 FTEs). If children who are underserved experience greater access to care or if pediatric dentists provide a larger portion of services for children, demand could grow by 2,100 FTE dentists or by 10,470 FTE dentists, respectively.

Conclusions. The study results suggest that the supply of pediatric dentists is growing more rapidly than is the demand. Growth in demand could increase if pediatric dentists captured a larger share of pediatric dental services or if children who are underserved had oral health care use patterns similar to those of the population with fewer access barriers.

Practical Implications. It is important to encourage policy changes to reduce barriers to accessing oral health care, to continue pediatric dentists' participation with Medicaid programs, and to urge early dental services for children.

Key Words. Pediatric dentists; workforce; modeling; microsimulation; supply; demand.

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Trends in the prevalence of early childhood caries among young children in the United States support recommendations for early and regular use of oral health care services. Caries remains the most common chronic disease of childhood, affecting nearly one-fifth of children aged 5 years or younger and one-half of children aged 6 through 10 years.[1] Untreated dental disease can cause pain, functional impairments, and poor school performance,[2] and it can lead to loss of teeth or expensive restorative interventions.[3] Caries also makes a child more vulnerable to various systemic infections, which threaten not only oral health but also overall health and quality of life.[4]

Early childhood caries affects certain groups of children at higher rates than it does other groups. From 2011 through 2014, the prevalence of untreated caries in the primary teeth of young children (aged 2-8 years) varied according to age and race or ethnicity.[5] Among 6- through 8-year-old children, the prevalence was 17.4%; the prevalence among children aged from 2 through 5 years was 10.9%. A higher percentage of Hispanic (19.4%) and non-Hispanic black children (19.3%) had untreated caries than did non-Hispanic white children (9.5%).

In a study conducted by the American Dental Association's (ADA) Health Policy Resources Center, researchers found that use of dental services by all children increased from 2006 through 2016.[6] Use of dental services by children insured by Medicaid or Children's Health Insurance Programs increased by 15.1% during this period partly because of growth in provider participation in

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the safety net, greater oral health care participation in state Medicaid programs,[7] and increased numbers of both pediatric and general dentists.

Pediatric dentists play a key role in ensuring access to high-quality oral health care for children from birth through young adulthood and for people with special health care needs. Pediatric dentistry is the only ADA-recognized dental specialty that is age defined; specialty training emphasizes clinical competencies to care for children. Although general dentists are trained in care for patients across the life span, standards for predoctoral education do not require substantial exposure to pediatric dentistry.[8]

In 2016, the ADA listed 196,468 dentists of whom 7,583 (3.9%) were pediatric dentists.[9] This number indicated an 80.0% increase in the number of pediatric dentists since 2001 when the number was 4,213. The distribution of these care providers varied according to state; the ratio of pediatric dentists to children was lowest in states with a larger proportion of rural populations.[9]

In 2007, Solomon[10] performed a geographic analysis and found that pediatric dentists have a higher propensity to practice in zip codes with large, urban populations; a higher number of general dentists; a high percentage of the population younger than 18 years; and positive socioeconomic characteristics, including high income and education levels. The American Academy of Pediatric Dentistry (AAPD) commissioned this study to evaluate the adequacy of the current and anticipated future supply of pediatric dentistry professionals to ensure that children receive recommended dental services.

METHODS

Supply and demand projections came from a health workforce tool that investigators have used to model the health care workforce for a wide variety of health occupations, including dentists.[11-15] We provide a brief summary of the data, methods, and assumptions for modeling supply and demand, with additional information provided in a technical appendix (available online at the end of this article).

Supply modeling

The microsimulation approach to model future supply involved using deidentified, individual-level data about the pediatric dentistry workforce to simulate career decisions on the basis of dentist age and sex and external factors that could affect key supply determinants. Modeling future supply started with information about supply; added new entrants on the basis of the training pipeline; and modeled patterns of hours worked, retirement, and state-to-state migration. We used sensitivity analysis to model different assumptions about key supply determinants.

Supply modeling started with the estimated 6,530 active pediatric dentists in the United States in 2016, as reflected by AAPD membership data and adjusting for the 6% of pediatric dentists who are not AAPD members.[16] The status quo supply scenario assumed 448 new pediatric dentists enter the workforce each year and reflected that 448 people (63.6% female) enrolled in pediatric dentistry residency programs in 2015 and 2016.[17] We calculated the age distribution of new dental school graduates on the basis of birth year and geographic distribution across states by using new member data from the AAPD since 2010.

To simulate workforce participation, we collected information about patient care hours worked per week and age of intended retirement via an online survey of pediatric dentistry practice in 2016. The survey sampling frame consisted of all pediatric dentists in 2017 who were AAPD members with a US address. We applied sample weights to the 2,546 completed surveys (39.1% response rate) to ensure representativeness. We used ordinary least squares regression analysis to model total weekly patient care hours across primary and secondary settings, with dentist age group and sex as explanatory variables. For dentists younger than 50 years, we modeled a small probability of attrition owing to mortality on the basis of US mortality rates. For dentists 50 years or older, we calculated age-dependent annual attrition probabilities by using survey responses indicating planned retirement age with sample weights proportional to their current age. We assumed all dentists retired by age 75 years.

We simulated the probability of annual cross-state migration by using logistic regression with American Community Survey data (combined 2011-2015 files) on all dentists younger than 50 years. The dependent variable was whether the dentist's state of residence was different from the previous year's state of residence, with age and sex as explanatory variables.

ABBREVIATION KEY

AAPD: American Academy of Pediatric Dentistry.
ACS: American Community Survey.
ADA: American Dental Association.
FTE: Full-time equivalent.
MEPS: Medical Expenditure Panel Survey.
NA: Not applicable.

For the status quo supply scenario, we assumed continuation of pipeline and workforce participation patterns. We used early retirement and delayed retirement scenarios to model 2 years earlier or delayed retirement, on average, relative to current patterns. We used more graduates and fewer graduates scenarios to model the implications of 10% increases or decreases in the annual number of pediatric dentist graduates.

To compare future with current supply and supply with demand, we used the concept of a full-time equivalent (FTE) care provider. The use of FTE adjusted for the effect of changing demographic characteristics in the workforce over time. We defined an FTE as 32.6 hours per week in patient care activities (that is, the average hours worked by pediatric dentists in 2016) based on the average patient care hours reported in the survey of AAPD members.[16]

Demand modeling

We modeled demand for dental services among children and the derived demand for dentists under various scenarios according to market share of pediatric dental services. Demand modeling consisted of 3 components: developing a representative sample of the pediatric population in each state, projecting demand for pediatric dental services, and projecting the number of pediatric dentists required to meet demand for services under each scenario.

Population

The model contained a representative sample of the child population in each state constructed by combining data from the US Census Bureau's 2015 American Community Survey and the Centers for Disease Control and Prevention's 2014 and 2015 Behavioral Risk Factor Surveillance System files.[18,19] The constructed population database contained data for a sample of approximately 656,400 children. When we applied sample weights, this database was representative of the child population in each state (which at the national level summed to 73.6 million children aged 17 years or younger). For each child, the population database contained demographic characteristics (age, sex, race or ethnicity), socioeconomic characteristics (household income, medical insurance type [information was unavailable about dental insurance]), and residence in a metropolitan or nonmetropolitan area. Using state-level population projections (calibrated to be consistent with the US Census Bureau's national population projections), we scaled the sample weights for individual people to reflect projections of the number and demographic characteristics of children from 2015 through 2030.

Dental Use Forecasting Equations

We determined use patterns by analyzing approximately 50,000 children in the pooled 2010 through 2014 files of the Medical Expenditure Panel Survey (MEPS).[20] MEPS is an annual set of large-scale surveys of families and individual people and their medical care providers and employers. If a survey respondent reports a dental visit during the previous quarter, MEPS obtains the permission to contact the provider and extract information from dental charts regarding type of care and cost information. MEPS does not distinguish between visits to a pediatric dentist from visits to a general dentist. To model dental visits, we used the annual encounters related to dental issues (excluding prophylaxis and visits related to orthodontic procedures) as a dependent variable. Explanatory variables were demographic characteristics, including age (0-2, 3-5, 6-12, and 13-17 years), sex, race or ethnicity, medical insurance, Medicaid, family income range, and residing in a metropolitan area.

We modeled patterns of annual health care use by using Poisson regression (eTable, available online at the end of this article). We tested the model to compare Poisson with zero-inflated Poisson and zero-inflated negative binomial, which might better model patient characteristics correlated with no dental visits in addition to 1 or more visits per year. We found that root-mean square errors (comparing predicted with actual total visits) were low for all 3 models—ranging from 1.48% for zero-inflated negative binomial to 1.53% for Poisson. If we used zero-inflated negative binomial rather than Poisson, under the baseline scenario, demand for pediatric dentists in 2030 would be approximately 30 FTEs higher than the estimate generated using the Poisson regression.

Care Delivery

Demand for pediatric dentists is linked to demand for dental services. We modeled 5 scenarios related to the percentage of children's dental services delivered by pediatric dentists if access barriers were mediated or removed.

Scenario 1

We used this scenario to model continuation of care delivery. It reflects ADA survey estimates that the percentage of oral health care provided by pediatric dentists (versus that provided by general dentists) is approximately 43%, 40%, and 23% for children younger than 2 years, aged 2 through 4 years, and aged 5 through 17 years, respectively (American Dental Association, Health Policy Institute, unpublished data, November 2018).

Scenario 2

We used this scenario to model a hypothetical scenario. It reflects input from pediatric dentists who served on the project advisory panel, in which pediatric dentists provide all oral health care for children 4 years or younger, 80% of care for children aged 5 through 12 years, and 20% of care for children aged 13 through 17 years.

Scenario 3

We used this scenario to model a hypothetical scenario removing access barriers for disadvantaged populations assuming that all children have oral health care use patterns similar to those of children with fewer access barriers (that is, white, non-Hispanic, with insurance, and in the highest income bracket). This scenario approximates a needs-based scenario. If access barriers were removed, there would be a large initial surge in demand as pent-up demand from underserved populations was addressed, but care patterns eventually should reflect those of the children with few access barriers.

Scenarios 4 and 5

Scenario 4 builds on scenario 1 to model total FTE dentists, including general and pediatric dentists, providing pediatric care. Scenario 5 builds on scenario 3, but it models total FTE dentist (general and pediatric) demand if disadvantaged populations had oral health care use patterns like those of children with few access barriers.

RESULTS

In 2016, one-half of pediatric dentists were female (51.8%), three-quarters were younger than 54 years (76.9%), three-quarters were white (74.7%), and most were non-Hispanic (91.7%). Most pediatric dentists (74.6%) worked in a private dental practice either full time or part time (Table). Approximately one-fifth (21.2%) of pediatric dentists practiced in the Northeast; 17.6%, in the Midwest; 35.5%, in the South; and 25.8%, in the West.

We estimated that the national ratio of pediatric dentists to children in the United States in 2016 was approximately 9 FTE pediatric dentists per 100,000 children. The ratios varied substantially across regions and states (Figure 1). The Northeast and West regions averaged 12 FTEs, whereas the South and Midwest regions averaged only 7 or 8 FTEs per 100,000 children.

In each of the 5 supply scenarios, growth in the anticipated supply of pediatric dentists from 2016 through 2030 varied. Growth was highest under the scenario with an increased number of graduates (approximately 4,690 additional FTEs by 2030) and lowest under the scenario with a decreased number of graduates (3,400 additional FTEs) (Figure 2).

The demand scenarios projected demand for pediatric dentists from 2016 through 2030 under various conditions (Figure 3). First, if oral health care use and delivery patterns for children remained unchanged, demand would grow by only 140 FTEs. This flat growth reflects that the number of children in the United States is projected to increase slowly and that much of this growth is among minority populations with historically lower use of dental services. Second, if changes in policy reduced barriers to accessing care, according to the current market share, pediatric dentist demand would increase by approximately 2,100 FTEs by 2030. Lastly, if pediatric dentists provided a larger portion of the dental services supplied to children, then growth in demand could be substantial, approaching 10,470 FTEs.

Figure 4 presents projections of supply and demand for pediatric dentists under the various suppositions modeled. The supply projections and the status quo demand projections all start with 6,530 pediatric dentists, but each projection has different rates of growth. Comparing projected supply of pediatric dentists with projected demand suggests that supply is growing more rapidly than demand for services on the basis of changing demographic characteristics alone (that is, the status quo scenario). If policy or other changes could remove access barriers, then the status quo scenario

Table. Characteristics of survey respondents, 2016.*

CHARACTERISTIC	PEDIATRIC DENTISTS, NO. (%)
Sex	
Male	1,196 (48.2)
Female	1,283 (51.8)
Age, y	
Younger than 35	507 (20.4)
35-44	900 (36.3)
45-54	501 (20.2)
55-64	349 (14.1)
65 or older	223 (9.0)
Race	
White	1,261 (74.7)
Black or African American	77 (4.6)
American Indian or Alaska Native	7 (0.4)
Asian or Pacific Islander	262 (15.5)
Other	80 (4.7)
Ethnicity	
Hispanic	141 (8.3)
Non-Hispanic	1,556 (91.7)
Practice Type	
Private dental practice	1,733 (74.6)
Large group multispecialty	152 (6.5)
Large group specialty practice	153 (6.6)
Other setting	286 (12.3)
Practice Location	
Northeast	523 (21.2)
Midwest	434 (17.6)
South	877 (35.5)
West	637 (25.8)

* Numbers vary across characteristics because not all respondents answered all questions, and percentages do not necessarily total 100% owing to rounding.

would shift up, starting at demand for 8,360 pediatric dentists. Under the scenario with increased market share, the demand for pediatric dentists would be higher, starting at demand for 16,520 in 2016. The scenarios starting with 26,830 and 34,290 FTEs reflect total estimated FTE dentist demand to serve children, recognizing that much of this care is and will continue to be provided by general dentists.

DISCUSSION

In this study, we found that the supply of pediatric dentists in the United States was growing. In 2016, the estimated supply was 6,530 FTE pediatric dentists, or 9 FTEs per 100,000 children. Under the status quo scenario, if annual production of new pediatric dentists continues at the 2016 rate, by 2030, supply is projected to reach approximately 10,560 FTEs, an increase of approximately 4,030 FTEs or 62%. This projection would result in approximately 14 FTEs per 100,000 children.

Pediatric dentists provide approximately 26% of dental services delivered to children (American Dental Association, Health Policy Institute, unpublished data, November 2018). If these use and delivery patterns persist in the future, demand would not increase appreciably from current levels, growing from 6,530 FTE pediatric dentists in 2016 to 6,670 FTEs in 2030, a net increase of 140

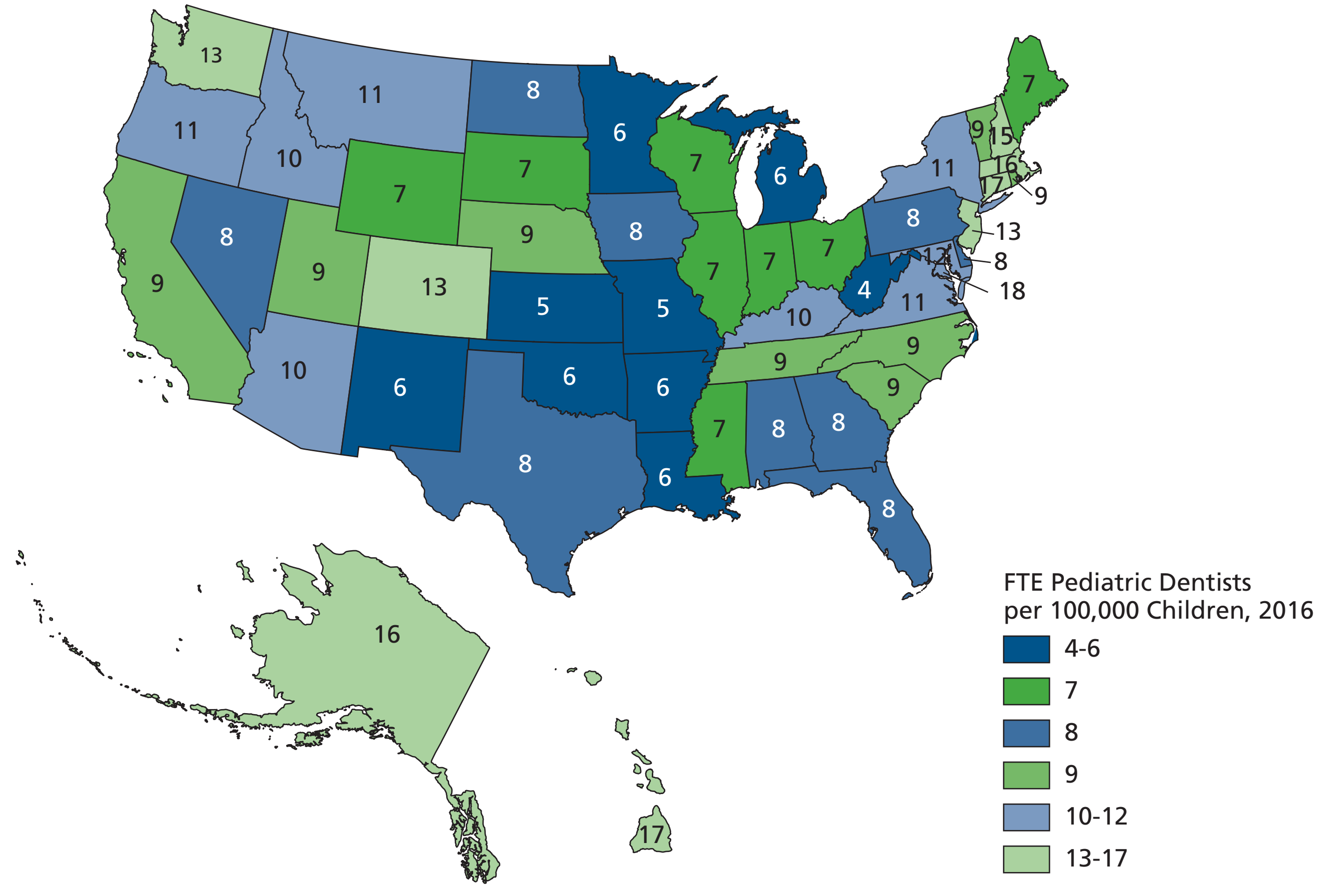

Figure 1. Map showing number of full-time equivalent pediatric dentists per 100,000 children, 2016. Source: American Academy of Pediatric Dentistry,[16] US Census Bureau.[21] FTE: Full-time equivalent.

FTEs or 2%. This is a noticeable contrast with the anticipated supply in 2030 (10,560 FTEs), if production levels of new professionals continue. However, the modeling scenarios also show that demand could grow substantially if the specialty captured a larger share of the demand for pediatric dental services. In modeling scenario 2 in which pediatric dentists provide approximately 62% of the oral health care received by children in the United States, estimated demand is approximately 16,520 FTE or 2.5 times the current level of FTE demand. Although this is the most optimistic and perhaps least likely of the proposed scenarios, modeling "ideal" use of pediatric dental services shows the substantive outcome on demand if the proportionate share of children using services increased. Although demand for pediatric dentists is unlikely to grow substantially on the basis of population demographic characteristics, it is plausible that demand could increase by shifting a portion of the care provided to children by general dentists to pediatric dentists and by implementing policies that improve access to care, especially for underserved minority populations and communities.

Another pertinent finding relative to future demand for pediatric dentistry services concerns unmet need for dental services among certain population groups, which are also those experiencing the greatest growth in the United States. Hispanic children used 24% fewer services, black children used 39% fewer services, and all other races used 14% fewer services than did white, non-Hispanic children controlling for age, sex, insurance status, and family income. Similarly, children without medical insurance (a proxy for no dental insurance) had only one-half as many dental visits as did children with insurance. Children in low-income families had 10% to 20% fewer annual dental visits than did children in households with annual incomes exceeding $75,000. If children who are underserved had oral health care use patterns similar to those of the population with fewer access barriers (that is, white, non-Hispanic children, with insurance, and in the highest income bracket), then total demand for dentists (including general and pediatric dentists) would increase from 26,830 FTEs in 2016 to 35,330 FTEs in 2030. If pediatric dentists, at a minimum, maintained their market share, then demand for pediatric dentists would increase from 6,530 FTEs to approximately 8,630 FTEs.

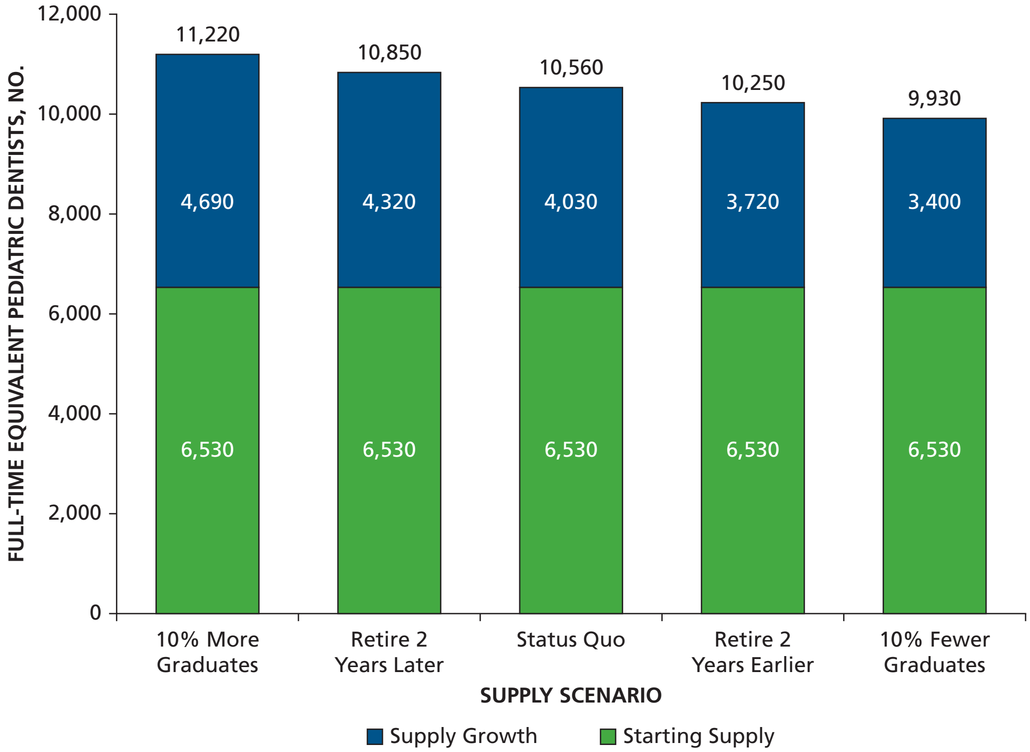

Figure 2. Chart illustrating full-time equivalent starting pediatric dentist supply in 2016, projected net growth in supply from 2016 through 2030 under the scenarios modeled, and projected total supply in 2030.

In the modeling for this study, we used 2010 through 2014 use patterns of dental services of children in the United States as a baseline measure of demand. The proposed scenarios are unable to anticipate the effect of change in a variety of factors that could affect future demand for dental services. These include changes in Medicaid policy affecting the quality or quantity of dental benefits for children, increased rates of referrals of children to pediatric dentists by pediatricians and family medicine clinicians, improvements in oral health literacy in the population of adults parenting or caring for young children, greater use of preventive technologies and materials including dental sealants and silver diamine fluoride, growth or reduction in rates of community water fluoridation, and narrowing of oral health disparities among certain populations of children. Modeling expected supply and demand for a health profession is challenging because the health care system in which these clinicians work is large, dynamic, and highly regulated. Unanticipated future changes in health policy may have substantial effects on the future behavior of the health care delivery system, including the professionals who supply health care services. Thus, modeling supply and demand is an imprecise science. However, in the microsimulation model we used for this study, we used predictive probabilities, derived from both endogenous and exogenous factors, to approximate anticipated future scenarios.

Our study had other limitations. First, although the prediction equations modeling use of dental services included demographic characteristics, socioeconomic information, having insurance, and other factors, we omitted additional contributors to demand for services. For example, ongoing efforts to promote good oral health practices among children could reduce demand for oral health services. Second, efforts to educate general dentists about providing care for infants and young children could reduce some need to redirect care to pediatric dentists. Third, there is uncertainty in key supply inputs such as trends in retirement patterns and number of pediatric dentists trained in future years. We conducted sensitivity analysis for these inputs. Continued monitoring of the pediatric dental workforce for future planning is necessary to reflect the availability of new data and an evolving health care system.

CONCLUSIONS

In the hypothetical scenarios selected, we modeled the effect of changes in dentists' years of practice, changes in access to dental services for children who are underserved, or increases in

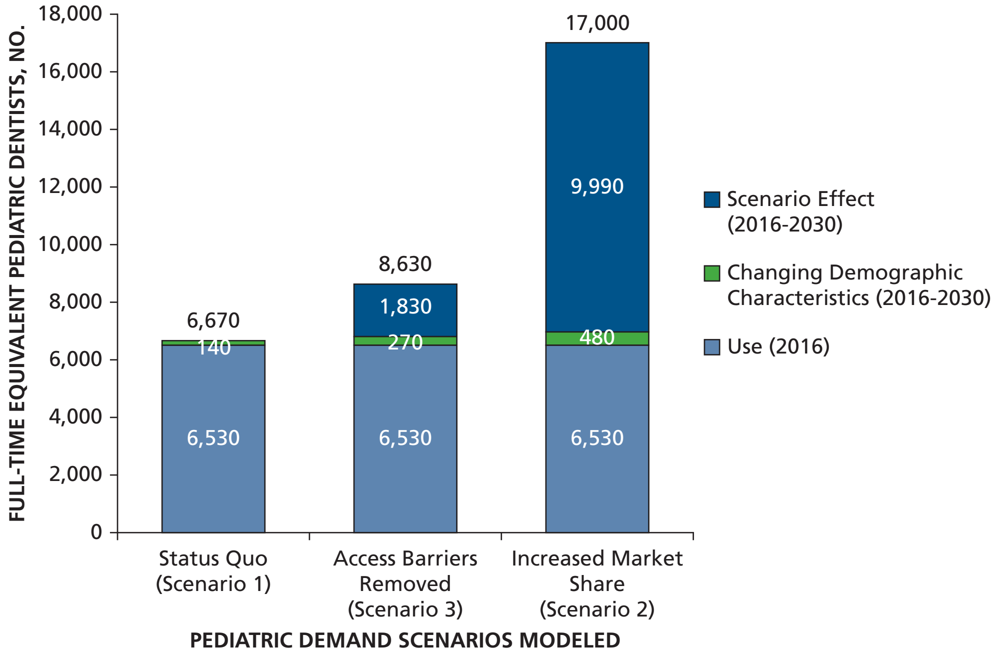

Figure 3. Chart illustrating projected net growth in full-time equivalent pediatric dentist demand from 2016 through 2030 under the 3 scenarios modeled for pediatric dentist demand, ranging from net growth of 140 through 10,470 under these scenarios.

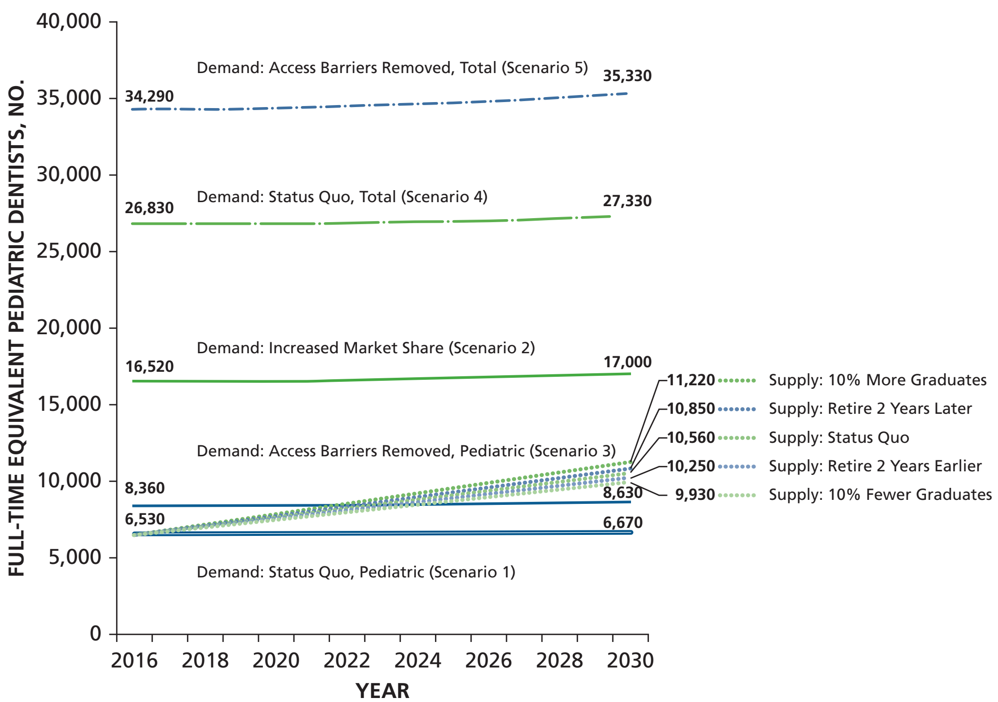

Figure 4. Chart illustrating projections of supply and demand for full-time equivalent pediatric dentists from 2016 through 2030 under the various scenarios modeled.

market share for pediatric dentists on supply and demand for pediatric dentists over 15 years. Results of the comparison of projected future supply of pediatric dentists with anticipated future demand on the basis of current patterns of production of new dentists and departures from practice (the status quo scenario) suggest that the supply of pediatric dentists is growing more rapidly than is demand for pediatric dental services. However, in scenarios modeling removal of access barriers to oral health care for children who are underserved and provision of a larger portion of dental services for children by pediatric dentists, demand for the services of pediatric dentists would increase noticeably. Although these models produced widely varying results, each is useful, in context, as a tool for continual monitoring of supply and demand for the pediatric dentistry workforce over the near future. ■

SUPPLEMENTAL DATA

Supplemental data related to this article can be found at: https://doi.org/10.1016/j.adaj.2019.02.025.

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APPENDIX

Modeling pediatric dentist supply and demand

This appendix provides additional detail about the methods for modeling supply and demand for pediatric dentists.

SUPPLY MODELING

Age distribution of new graduates

The estimated age distribution of the new graduates (eFigure 1) is based on data from pediatric dentists who became American Academy of Pediatric Dentistry members since 2010 and compares birth year with graduation year. In the microsimulation model, each new graduate randomly is assigned an age reflecting this distribution.

Hours worked patterns

The Survey of Dental Practice of Pediatric Dentists asked number of hours per week in total and treating patients in primary and secondary settings. We summed patient care hours per week across primary and secondary settings and estimated the relationship with dentist demographic characteristics by using ordinary least squares regression analysis. Hours worked per week tended to decrease with age, especially starting at the age of approximately 65 years (eTable 1). Controlling for age, male pediatric dentists worked approximately 2.85 more hours per week than did their female colleagues.

Retirement patterns

For pediatric dentists younger than 50 years, there was a small annual probability of attrition from the workforce (for example, because of disability or mortality). For pediatric dentists 50 years or older, the supply model used age-dependent annual attrition probabilities to simulate care providers leaving the workforce. We estimated retirement patterns by using survey questions that asked about intention to retire. The survey asked respondents to indicate whether they had any plans to retire and, if so, at what age they planned to retire. As expected, the closer one's age was to traditional retirement ages, the more likely the response of a planned retirement age. Using this information, we calculated annual attrition rates from ages 50 through 74 years (eFigure 2). For modeling, we assumed that by age 75 years, all dentists have retired. To account for respondents likely having a more accurate estimation of their retirement age when that age is closer to their current age, we gave responses weights proportional to the respondent's current age. The resulting pattern indicated that approximately two-thirds of pediatric dentists will retire by age 65 years and that more than 90% will retire before age 75 years. Using this retirement pattern, the supply projections predicted from 150 through 200 pediatric dentists retiring annually from 2016 through 2030.

Cross-state migration patterns

The supply model simulated the probability that pediatric dentists in each state might move to another state. In this analysis, we used logistic regression with American Community Survey (ACS) data (combined 2011-2015 files) for all dentists (the ACS does not distinguish between general dentists and pediatric dentists). Similar to investigators modeling other health professions, we limited our cross-state migration analysis to dentists younger than 50 years because of both small sample size concerns and concerns that for older health care professionals it is difficult to distinguish between a person whose move is to work in another state or whose move is related to retirement. The dependent variable was whether the person's state of residence was different from the previous year's state of residence (1 = different; 0 = same). The explanatory variables were age and sex, the same variables we used to model hours worked patterns.

On average, approximately 3.2% of dentists moved across state lines each year. The propensity to move across states, however, differed according to a dentist's demographic characteristics (eTable 2). Dentists aged 30 through 34 years had the highest propensity to move to a different state, with move propensity rapidly decreasing among older dentists. Women were less likely to move across states (odds were 0.66 that of men).

After using these regression coefficients to assign interstate moves to pediatric dentists on the basis of their age and sex, we used the model to assign the pediatric dentists a new state on the basis of the distribution of destination states of dentists moving from 1 state to another in the 2011 through 2015 ACS. For states with 3,000 or fewer dentists in the weighted ACS counts, the model used the state's count of migrants from the ACS multiplied by the state's proportion of the overall count of dentists in the state's census division in an attempt to correct for the small sample of migrant dentists identified in states with small populations.

DEMAND MODELING

This section presents an overview of the data and approach for modeling demand for dental services among children and the derived demand for pediatric dentists under various scenarios according to market share of pediatric dental services. The approach for modeling demand consisted of 3 components: developing a representative sample of the population in each state, projecting demand for pediatric dental services, and projecting the number of pediatric dentists required to meet demand for services under the various scenarios modeled.

Population database

The model contained a representative sample of the child population in each state constructed by combining data from the US Census Bureau's 2015 ACS and the Centers for Disease Control and Prevention 2014 and 2015 Behavioral Risk Factor Surveillance System files (eTable 3). The resulting constructed population database contained data for a sample of approximately 656,400 children, and when we applied sample weights, this database was representative of the child population in each state (which at the national level summed to 73.6 million children aged 0-17 years). For each child, the population database contained demographic characteristics (age, sex, race or ethnicity), socioeconomic characteristics (household income, medical insurance type [information about dental insurance was unavailable in the population file]), and residence in a metropolitan or nonmetropolitan area. Using population projections obtained for each state (and calibrated to be consistent with the US Census Bureau's national population projections), we scaled the sample weights for individual people in the population database to reflect projections of the number and demographic characteristics of the population from 2015 through 2030.

Dental use forecasting equations

Patterns of health-seeking behavior came from analysis of approximately 50,000 children in the pooled 2010 through 2014 files of the Medical Expenditure Panel Survey (MEPS). MEPS is an annual set of large-scale surveys of families and individual people and their medical care providers and employers. Each quarter, individual people are interviewed, and information is collected and updated for that person (for example, medical conditions and insurance coverage), the family (for example, family income), and use of health care services during the previous quarter. If a person responds that he or she had a dental visit during the previous quarter, for example, MEPS obtains the person's permission to contact the care provider and extract information from dental charts regarding type of care received and cost information. Hence, the Medical Provider Component of MEPS collects information from providers of medical care that supplements the information collected from people in the household survey component of MEPS. The visits file in MEPS does not distinguish between visits to a pediatric dentist from visits to a general dentist (although the data allow one to distinguish reasons for the visit).

To model dental visits, we used Poisson regression for which the dependent variable was annual encounters related to dental issues (excluding prophylaxis and visits related to orthodontic procedures). eTable 4 displays the Poisson regression output as rate ratios. For example, controlling for other patient characteristics, a non-Hispanic black child had only 61% as many visits to a dentist as did a non-Hispanic white child (the comparison group). Annual dental visits increased with child age. For example, compared with the number of visits for children aged 13 through 17 years, the number of visits was only 92.5% as much for children aged 6 to 12 years, 74.1% as much for children aged 3 through 5 years, and 22.7% as much for children aged 2 years or younger. We did not include having dental insurance in the study because dental insurance was unavailable in the files used to create the population file to which we extrapolated these MEPS-derived prediction equations.

Having medical insurance was correlated with having dental insurance and thus served as a proxy variable. Children with medical insurance had 80.2% more dental visits per year than did children without medical insurance (controlling for demographic characteristics and other factors). If the child was receiving Medicaid, the child had a 3.2% higher visit rate to dentists (although this estimate was not statistically significant). Compared with an annual family income of $75,000 or higher, lower income was associated with fewer dental visits. For example, families with income in the $15,000 through $20,000 range had only 81.4% as many dental visits per year as did families earning more than $75,000 annually (controlling for insurance status and demographic characteristics). Children living in metropolitan areas had only 82% as many visits to a dentist as did similar children living in nonmetropolitan areas.

Appendix eTable 1. Ordinary least squares regression analysis of weekly hours worked patterns.

PARAMETER*	HOURS COEFFICIENT	STANDARD ERROR
Intercept	37.32†	0.55
Age, y		
35-44	−2.92†	0.58
45-54	−3.67†	0.65
55-59	−3.07‡	0.90
60-64	−4.35†	8.87
65-69	−7.49†	0.99
70 or older	−8.20†	1.24
Female	−2.85†	0.43

* Comparison groups are age younger than 35 years and male. † Statistically significant at the 1% level ($R^2 = 0.05$). ‡ Statistically significant at the 5% level ($R^2 = 0.05$).

Appendix eTable 2. State outmigration patterns.*

PARAMETER	ODDS RATIO (95% CONFIDENCE INTERVAL)
Age, y	
Younger than 30 [Reference]	1.00 (NA†)
30-34	0.44 (0.27 to 0.71)
35-39	0.22 (0.13 to 0.38)
40-44	0.13 (0.07 to 0.25)
45-49	0.07 (0.03 to 0.16)
Sex	
Male [Rreference]	1.00 (NA)
Female	0.66 (0.44 to 0.99)

* The authors based the analysis on logistic regression. Odds ratios indicate the relative likelihood of moving to a new state in relation to that of the comparison group. The comparison groups are male and age younger than 30 years. † NA: Not applicable.

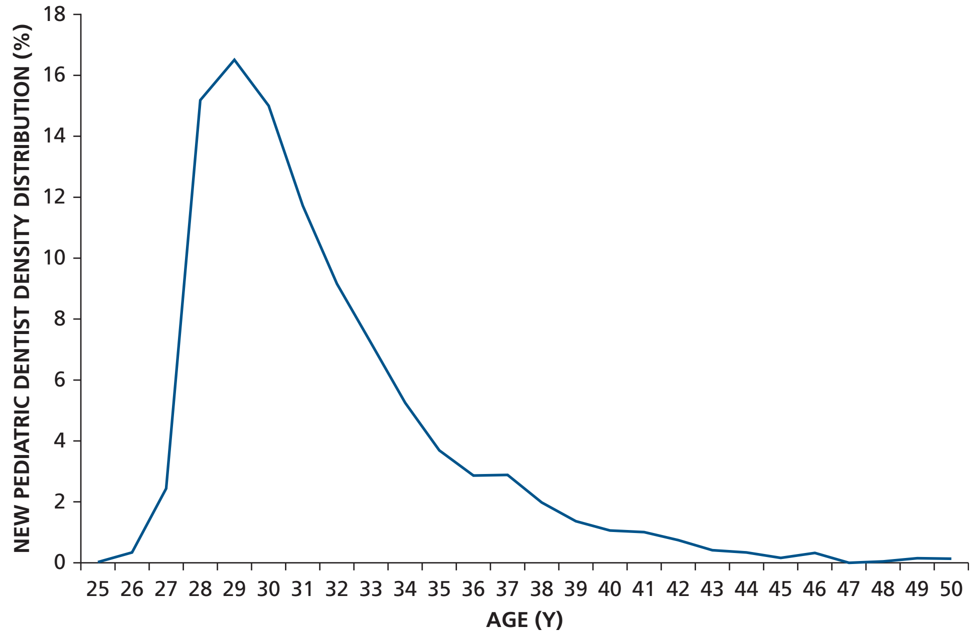
Appendix eTable 3. Summary of demand modeling data sources.

MODEL COMPONENT	DATA SOURCES
National or State Population Files	2015 American Community Survey; 2014 and 2015 Behavioral Risk Factor Surveillance System
Weights for Population Projections	2014 US Census Bureau national population projections; state population projections to estimate demand according to region and metropolitan or nonmetropolitan area
Dental Use Equations	2010 through 2014 pooled Medical Expenditure Panel Survey
Pediatric Dentist Staffing Ratios	Demand calculated from staffing ratios and calibrated to demand for general and pediatric dentists; pediatric dentist demand backed from the total based on proportion of dental care provided by pediatric dentists according to child age group

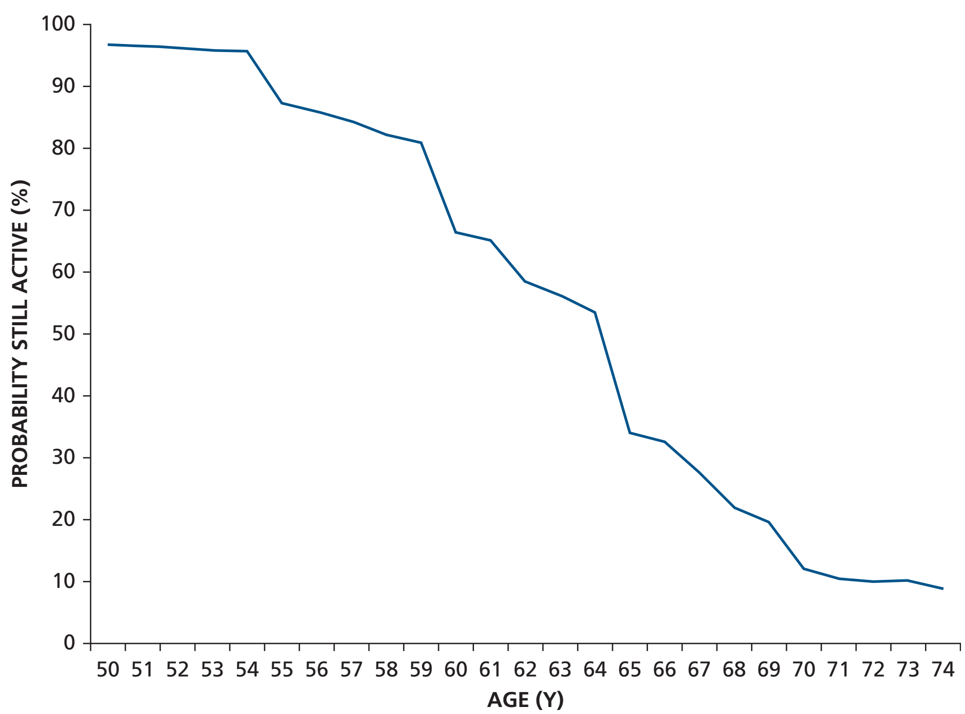
eTable. Regression results modeling annual dental visits for children.

PARAMETER*	VISIT RATE RATIO	STANDARD ERROR
Race or Ethnicity		
Black non-Hispanic	0.607†	0.028
Other non-Hispanic	0.859†	0.031
Hispanic	0.761†	0.022
White non-Hispanic	1.000	NA‡
Male	0.911†	0.018
Age, y		
0-2	0.227†	0.045
3-5	0.741†	0.027
6-12	0.925†	0.020
13-17	1.000	NA
Medical Insurance		
Insured	1.802†	0.041
Medicaid	1.032	0.025
Household Income, $		
< 10,000	0.864	0.036
10,000 to < 15,000	0.869†	0.043
15,000 to < 20,000	0.814†	0.044
20,000 to < 25,000	0.908§	0.041
25,000 to < 35,000	0.809†	0.036
35,000 to < 50,000	0.811†	0.032
50,000 to < 75,000	0.860†	0.029
75,000 or higher	1.000	NA
Metropolitan Area	0.820†	0.033

* The parameter estimates in this table are rate ratios based on Poisson regression. These ratios reflect how a person with the characteristic differs in terms of annual use of dental services relative to someone in the comparison group or without the characteristic. The comparison groups are non-Hispanic white, female, ages 13 through 17 years, uninsured, and household income $75,000 or higher. † Statistically significant at the 1% level. ‡ NA: Not applicable. § Statistically significant at the 5% level.



eFigure 1. Chart illustrating estimated age distribution of new graduates.



eFigure 2. Chart illustrating annual attrition rates from ages 50 through 74 years.