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Research Brief

Supply of Full-Time Equivalent Dentists in the U.S. Expected to Increase Steadily

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Key Messages

- *We update our earlier estimates of the future supply of dentists in the U.S. by revising some of our assumptions. We continuously monitored key dentist labor market decisions in recent years and concluded these changes were enough to warrant a revised analysis.*
- *Under what we consider to be the most probable scenario, the per capita supply of dentists in the United States is projected to increase through 2037 even after adjusting for expected changes in hours worked and patient visits due to dentist age and gender composition.*
- *Understanding the future evolution of the total supply of dentists contributes only partially to the central policy question of whether the dental workforce will be able to meet population needs. The issue of provider adequacy is far more complex and further research is needed.*

Introduction

With any type of health care service, having a sufficient number and distribution of providers is critical to ensuring population access to needed care. In the dental care sector, there is intense debate at the federal and state level on the adequacy of the dentist workforce in terms of meeting current and future population needs. The Health Resources and Services Administration (HRSA) estimates that there is a current shortage of 10,802 dentists in the United States.[1] Several dental schools that have opened in recent years cite insufficient supply of dentists as a key reason why more dental school graduates are needed.[2,3,4] Alternatively, a recent analysis suggests evidence for a surplus of dentists by 2040.[5]

Assessing the adequacy of the dentist workforce is not simply a supply-side issue. The demand for dental care on the part of the population, the mix of patients in terms

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of type of payer and geographic location, and a host of other factors determine whether the current and future dentist workforce is sufficient. For example, the aggregate supply of dentists may be adequate in size when compared to the aggregate demand for dental care. However, there may be an insufficient number of dentists relative to need or demand for dental care among disadvantaged populations or in certain geographic areas. The issue of dentist workforce adequacy is complex and further conceptual and empirical work is needed. This is true not just of dentistry, but other types of health care services.[6]

In this research brief, we project the number of dentists in the United States through 2037 with revised assumptions compared to our earlier analysis. Specifically, we modified our previous analysis by (1) more closely examining how retirement decisions are influenced by business cycles and (2) recognizing that some dental school graduates never become "professionally active" by our model's criteria and, therefore, should not be counted as practicing dentists. We do not attempt to make any judgments on the adequacy of the future dentist workforce. This would require further investigation, incorporating demand-side factors and a host of other issues. Nevertheless, we feel our analysis is a major contribution to the evidence base as it leverages unique data and builds modeling scenarios based on empirical analyses of dentist behavior. It also incorporates the effect of a dentist workforce with a shifting age and gender profile on dentists' hours worked and volume of patient visits.

Results

In 2017, there were 198,517 practicing dentists in the United States. This translated to 60.9 dentists per 100,000 population.

Our workforce projection model uses historical trends in inflows of dentists to and outflows of dentists from the workforce to inform various assumptions about future inflows and outflows. We redefined our "baseline" modeling scenario on new assumptions that we believe are most probable: (1) that retirement rates over the next 20 years will correspond to their historical patterns under typical U.S. business cycles and (2) that the annual number of U.S. dental school graduates will increase through 2022 and then remain constant. Under this scenario, the unadjusted number of dentists per 100,000 population will increase from 60.9 in 2017 to 63.7 in 2037. Our previous analysis predicted an increase to 65.7 in 2035. Thus, our new analysis predicts slower growth in the size of the dentist workforce.

Dentists vary by gender and age group in the number of hours they work and the number of patients they treat per week. To account for this, we adjusted our projections for hours worked and number of patient visits. Our baseline modeling scenario seen in Figure 1 indicates that the projected number of dentists per 100,000 population will increase even after adjusting for expected changes in hours worked and patient visits. In other words, the number of full-time-equivalent dentists per capita is expected to grow.

Figure 2 takes the same data from Figure 1 but summarizes changes over time from 2017 to 2037. The projected growth rate of the number of dentists per capita between 2017 and 2037 is 4.5 percent. Adjusting for expected shifts in hours worked due to the age and gender profile of the future dentist workforce, the growth rate of the supply of full-time equivalent dentists is lower, at 3.5 percent. Replicating the same adjustment for patient visits, the growth rate is 2.6 percent. These two adjusted growth rates are lower because of the projected decline in average hours worked per dentist.

As our methods section describes, we defined three assumptions about future inflows of dentists into the

workforce and three assumptions about future outflows of dentists from the workforce (Table 1). By pairing these assumptions in all possible combinations, we generated nine possible scenarios of workforce projections. Table 2 contains all nine scenarios adjusted for expected shifts in hours worked. Table 3 contains the scenarios adjusted for expected shifts in the number of patient visits per dentist. The baseline scenario denotes what we feel is the most probable scenario.

Taken together, the nine scenarios in Table 2 suggest that the dentist workforce per capita, adjusted for hours worked, will change in 20 years under all of our modeling scenarios: from 55.4 to some number between 55 and 60. This range of outcomes is greatly influenced by choice of assumption of the future number of U.S. dental school graduates. If the number of graduates increases or decreases by more than 1 percent per year relative to our baseline scenario (from 2022 through 2037), the future supply of dentists would fall outside the bounds described in Table 2.

The same principle applies to Table 3 where results are adjusted for expected shifts in patient visits. The nine scenarios represented in Table 3 suggest that the adjusted dentist workforce per capita will change in 20 years from 51.7 to a number between 51 and 55. If future conditions fall outside the bounds defined by our assumptions, the future dentist supply would fall outside the bounds of these scenarios.

Our baseline scenario also projects that the "de-aging" of the dentist workforce will continue. The share of dentists aged 55 and older increased from 27 percent in 2001 to a peak of 40 percent in 2013-2016.[7] This share decreased to 39 percent in 2017, and we project it will decrease to 35 percent in 2037. This finding originates from the opening of ten new dental schools[8] in recent years and the resulting additional graduates entering the workforce.

Discussion

Our dental workforce projection model, while conceptually straightforward, has the potential to generate numerous alternative scenarios based on different assumptions. We took considerable care to focus our analysis on what we believe are the most probable assumptions based on extensive analysis of the best available empirical data. We updated our assumptions as better information became available. We emphasize, however, that different sets of assumptions will yield different results and we plan on updating the model as market conditions change.

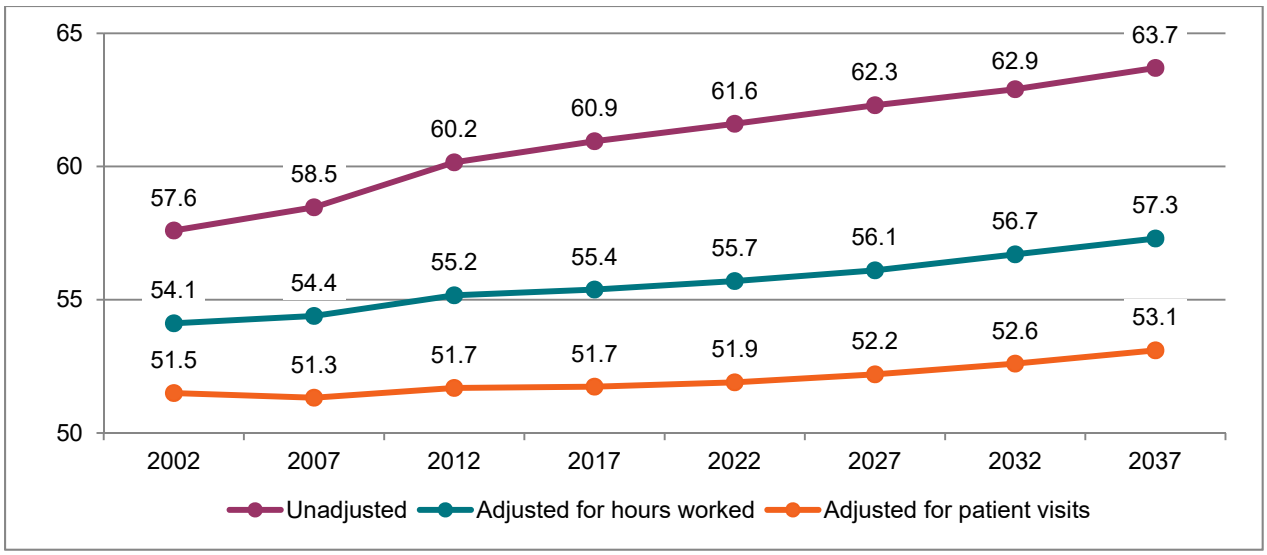
Our main finding is that under what we consider to be the most likely scenario, the per capita supply of dentists in the United States is projected to increase through 2037. More importantly, even after adjusting for expected reductions in hours worked and patient visits per dentist resulting from the age and gender profile of the dentist workforce, the supply of dentists is still expected to increase. Total inflows to the dentist workforce are expected to exceed total outflows, and this net gain is expected to outpace the projected growth of the U.S. population. Looking at alternative scenarios to what we feel is most probable, the vast majority still predict a stable or increasing supply of dentists.

As we noted in the introduction, our analysis needs to be interpreted carefully. Understanding how the total supply of dentists might evolve only partially contributes to the central policy question of whether or not there will be a shortage of dentists in the United States. The issue of provider adequacy is far more complex and even at the most aggregate level requires assessment of the demand for dentists. The future demand for dentists, in turn, will depend on the future demand for dental care among the population, the future evolution of productivity and efficiency of

dentists, and potential changes in the workforce mix within dental care delivery models. One analysis predicts that dental spending in the United States is expected to grow at much lower rates than in previous decades,[9] even after taking into account the aging of the population. Another analysis suggests that the demand for restorative dental care will continue trending downward.[10] At the same time, the Affordable Care Act has expanded dental coverage for certain groups, mainly children and low-income adults, and demand for dental care will likely increase among these groups.[11] While further work is needed, our results suggest that, at the aggregate level, the United States could be entering a period of expanding supply of dentists and flattening demand for dental care. The shifts in the age and gender profile of the dentist workforce do not affect these conclusions.

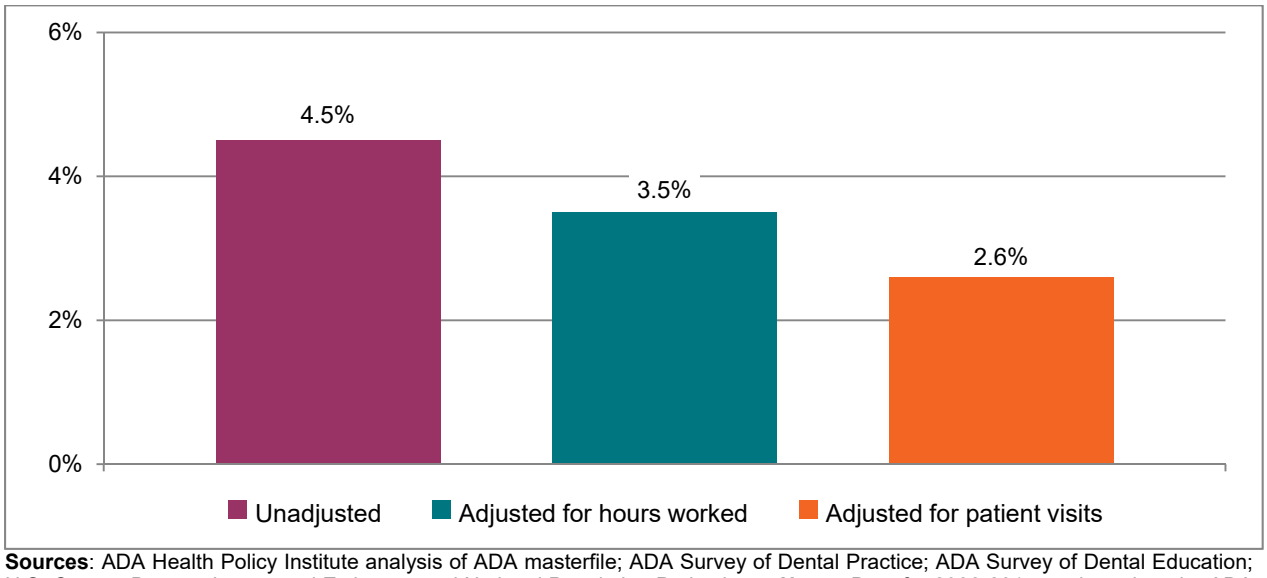
As we noted, highly aggregated national-level analyses like ours do not entirely address a key concern of policymakers: is the supply of providers adequate to meet the needs of key segments of the population? These key segments of the population are typically thought of according to geography (e.g., populations in rural versus urban areas) or by payer type (e.g., populations with Medicaid dental benefits versus commercial dental benefits). Answering this question requires much more sophisticated small-scale geographic analyses and comprehensive data on where Medicaid-accepting dentists are located. The Health Policy Institute is leading a comprehensive research agenda that is exploring such an analysis,[12] and we hope other future research on this topic contributes empirical evidence on this important policy issue.

Figure 1: Historical and Projected Dentists per 100,000 Population in the U.S., Baseline Scenario



Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Practice; ADA Survey of Dental Education; U.S. Census Bureau, Intercensal Estimates and National Population Projections. **Notes**: Data for 2002-2017 are based on the ADA masterfile. Results after 2017 are projected. Assumes (1) retirement rates over the next 20 years will correspond to historical patterns under typical U.S. business cycles and (2) the annual number of U.S. dental school graduates will increase through 2022 and then remain constant.

Figure 2: Percentage Increase in Projected Dentists per 100,000 Population in the U.S. from 2017 to 2037, Baseline Scenario



Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Practice; ADA Survey of Dental Education; U.S. Census Bureau, Intercensal Estimates and National Population Projections. **Notes**: Data for 2002-2017 are based on the ADA masterfile. Results after 2017 are projected. Assumes (1) retirement rates over the next 20 years will correspond to historical patterns under typical U.S. business cycles and (2) the annual number of U.S. dental school graduates will increase through 2022 and then remain constant.

Table 1: Assumptions for Inflows and Outflows Used in the Model

Three Inflow Assumptions
U.S. total annual dental school graduates will increase until 2022 and then increase 1% per year.
U.S. total annual dental school graduates will increase until 2022 and then remain constant.
U.S. total annual dental school graduates will increase until 2022 and then decrease 1% per year.
Three Outflow Assumptions
Outflow rates will be relatively low due to an economic downturn that occurs by 2022.
Outflow rates will correspond to long-term averages under typical U.S. business cycles.
Outflow rates will be relatively high due to the lack of an economic downturn by 2022.

Table 2: Summary of Workforce Projection under Nine Scenarios for Dentists per 100,000 Population, Adjusted for Hours Worked

Assumptions			Projections				
Inflow rate	Outflow rate influenced by	2017	2022	2027	2032	2037	Description
1% annual growth in graduates per year after 2022	Economic downturn by end-of-year 2022	55.4	56.5	56.9	57.9	59.5	Highest outcome
	Average U.S. business cycles	55.4	55.7	56.4	57.6	59.3	
	No economic downturn by end-of-year 2022	55.4	55.3	56.1	57.4	59.2	
Graduates per year remain constant after 2022	Economic downturn by end-of-year 2022	55.4	56.5	56.7	57.0	57.5	
	Average U.S. business cycles	55.4	55.7	56.1	56.7	57.3	Baseline scenario
	No economic downturn by end-of-year 2022	55.4	55.3	55.9	56.5	57.2	
1% annual decline in graduates per year after 2022	Economic downturn by end-of-year 2022	55.4	56.5	56.4	56.1	55.6	
	Average U.S. business cycles	55.4	55.7	55.9	55.7	55.4	
	No economic downturn by end-of-year 2022	55.4	55.3	55.6	55.6	55.3	Lowest outcome

Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Practice; ADA Survey of Dental Education; U.S. Census Bureau, Intercensal Estimates and National Population Projections. **Notes**: Data for 2017 are based on the ADA masterfile. Results after 2017 are projected.

Table 3: Summary of Workforce Projection under Nine Scenarios for Dentists per 100,000 Population, Adjusted for Patient Visits

Assumptions			Projections				
Inflow rate	Outflow rate influenced by	2017	2022	2027	2032	2037	Description
1% annual growth in graduates per year after 2022	Economic downturn by end-of-year 2022	51.7	52.6	52.9	53.7	55.1	Highest outcome
	Average U.S. business cycles	51.7	51.9	52.4	53.5	55.0	
	No economic downturn by end-of-year 2022	51.7	51.6	52.2	53.3	54.9	
Graduates per year remain constant after 2022	Economic downturn by end-of-year 2022	51.7	52.6	52.7	52.9	53.3	
	Average U.S. business cycles	51.7	51.9	52.2	52.6	53.1	Baseline scenario
	No economic downturn by end-of-year 2022	51.7	51.6	52.0	52.5	53.0	
1% annual decline in graduates per year after 2022	Economic downturn by end-of-year 2022	51.7	52.6	52.4	52.0	51.4	
	Average U.S. business cycles	51.7	51.9	51.9	51.7	51.2	
	No economic downturn by end-of-year 2022	51.7	51.6	51.7	51.6	51.1	Lowest outcome

Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Practice; ADA Survey of Dental Education; U.S. Census Bureau, Intercensal Estimates and National Population Projections. **Notes**: Data for 2017 are based on the ADA masterfile. Results after 2017 are projected.

Table 4: Historical Outflow Rates

	2002-2007	2003-2008	2004-2009	2005-2010	2006-2011	2007-2012	2008-2013	2009-2014	2010-2015	2011-2016	2012-2017
Age under 35	3.1%	2.8%	2.4%	2.5%	2.1%	2.0%	2.0%	2.1%	1.9%	2.3%	2.5%
Age 35 - 44	3.2%	3.3%	2.9%	2.9%	2.6%	2.5%	2.4%	2.5%	2.0%	2.2%	2.3%
Age 45 - 54	4.8%	4.8%	4.3%	4.4%	3.7%	3.6%	3.5%	3.8%	3.4%	3.8%	4.0%
Age 55 - 64	17.9%	17.5%	16.2%	14.8%	14.0%	13.2%	13.1%	14.1%	14.5%	15.3%	15.9%
Age 65 - 74	44.6%	41.5%	40.0%	38.8%	36.6%	32.7%	32.8%	34.7%	37.0%	39.2%	40.9%
Age 75 - 84	66.9%	63.0%	60.5%	59.4%	53.2%	50.1%	50.3%	52.5%	53.5%	58.2%	61.4%
Age 85 and older	90.0%	82.7%	76.2%	80.5%	74.9%	71.2%	68.1%	72.1%	73.4%	77.2%	80.6%
All ages 65 and older	49.2%	45.6%	43.9%	42.8%	39.8%	36.0%	36.1%	38.1%	40.2%	42.7%	44.6%

Source: ADA Health Policy Institute analysis of ADA masterfile. **Note**: Total outflow rates denote the percentage of dentists who had retired, whose license had lapsed, or who were deceased.

Figure 3: Historical Outflow Rates (Five Years Ending), Dentists Aged 55 and Under

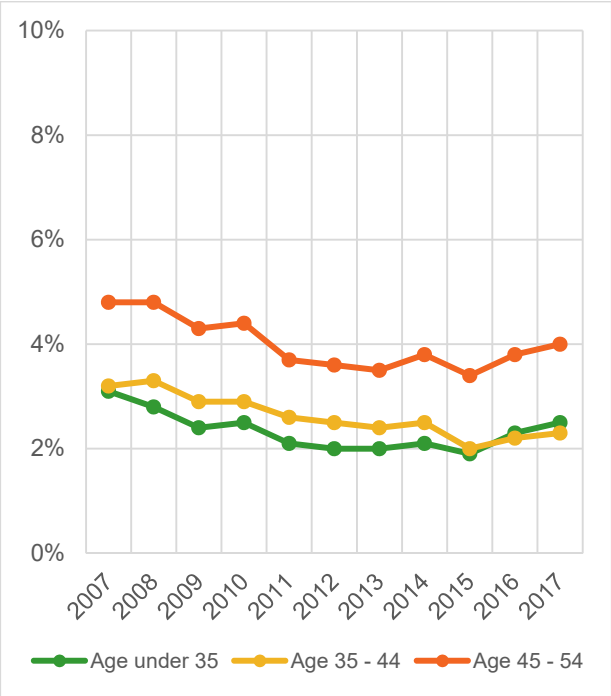
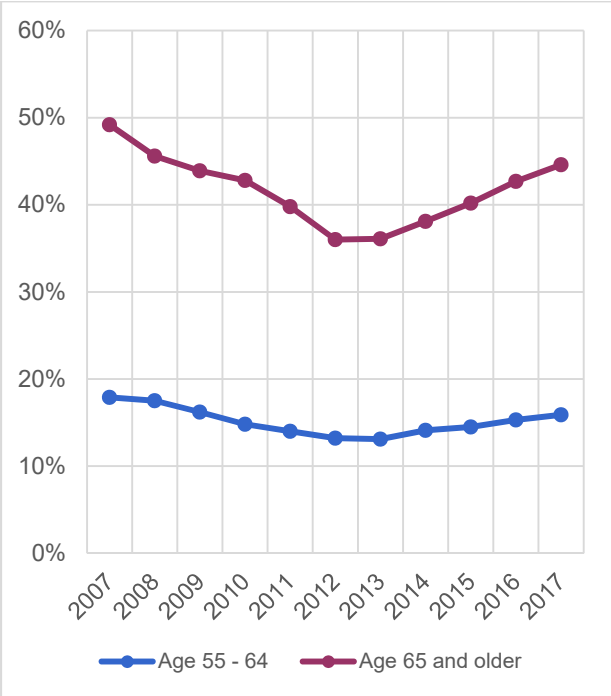


Figure 4: Historical Outflow Rates (Five Years Ending), Dentists Aged 55 and Older



Source: ADA Health Policy Institute analysis of ADA masterfile. **Note**: Total outflow rates denote the percentage of dentists who had retired, whose license had lapsed, or who were deceased.

Table 5: U.S. Business Cycle Expansions and Contractions

Years	Number of Cycles	Duration of Average Contraction	Duration of Average Expansion	Duration of Average Cycle
1945-2009	11	11.1 months	58.4 months	69.5 months

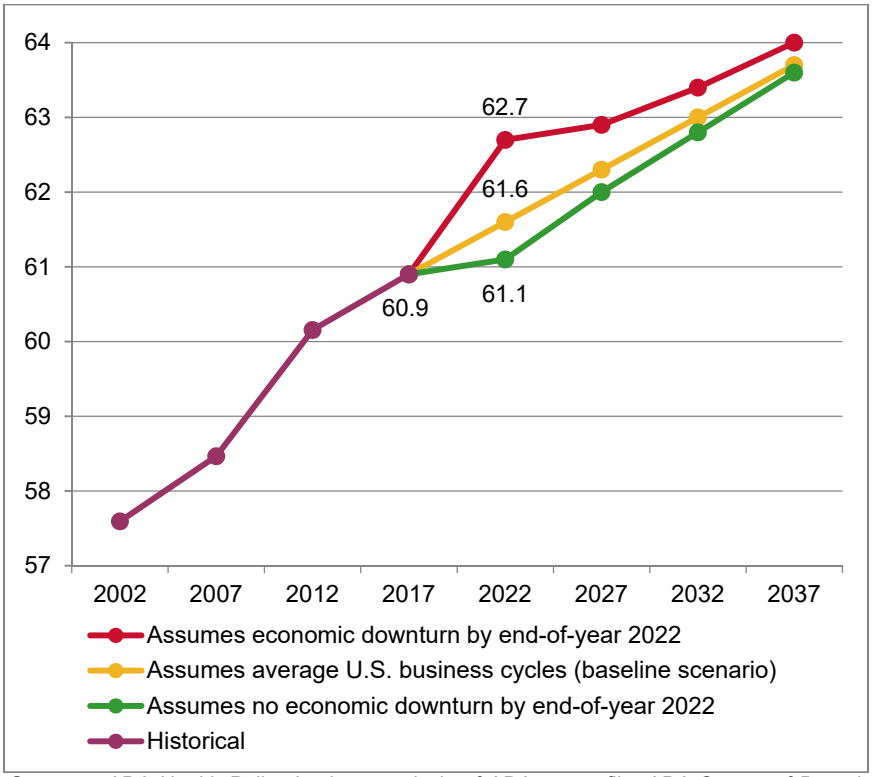
Source: National Bureau of Economic Research.

Table 6: Three Outflow Assumptions

	Economic downturn by end-of-year 2022		Average U.S. business cycles (baseline scenario)		No economic downturn by end-of-year 2022	
	2017-2022	2022-2037	2017-2022	2022-2037	2017-2022	2022-2037
Age under 35	2.1%	2.7%	2.7%	2.7%	2.8%	2.7%
Age 35 - 44	2.6%	2.7%	2.7%	2.7%	2.8%	2.7%
Age 45 - 54	3.7%	4.3%	4.3%	4.3%	4.4%	4.3%
Age 55 - 64	14.0%	16.4%	16.4%	16.4%	17.9%	16.4%
Age 65 - 74	36.6%	41.8%	41.8%	41.8%	44.6%	41.8%
Age 75 - 84	53.2%	62.4%	62.4%	62.4%	66.9%	62.4%
Age 85 and older	74.9%	83.6%	83.6%	83.6%	90.0%	83.6%

Source: ADA Health Policy Institute analysis of ADA masterfile. **Notes**: The three assumptions differ only in their percentages for the years 2017-2022. All three use the "average U.S. business cycles" percentages for the years 2022-2037. Total outflow rates denote the percentage of dentists who had retired, whose license had lapsed, or who were deceased.

Figure 5: Historical and Projected Dentists per 100,000 Population (Unadjusted), Scenarios With/Without Economic Downturn by End-of-Year 2022



Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Practice; ADA Survey of Dental Education; U.S. Census Bureau, Intercensal Estimates and National Population Projections. **Notes**: Data for 2002-2017 are based on the ADA masterfile. Results after 2017 are projected. Assumes the annual number of U.S. dental school graduates will increase through 2022 and then remain constant.

Table 7: Historical Dentist Inflows, 2007-2012

	U.S. Dental School Graduates	Foreign-trained Dentists	Relicensed Dentists	Dentists Returned from Retirement	Total
Age under 35	20,896	442	2	3	21,343
Age 35 - 44	3,350	785	243	17	4,395
Age 45 - 54	253	318	367	52	990
Age 55 - 64	15	114	266	109	504
Age 65 - 74	1	25	68	94	188
Age 75 - 84	0	4	15	43	62
Age 85 and older	0	0	1	3	4
Total	24,515	1,688	962	321	27,486

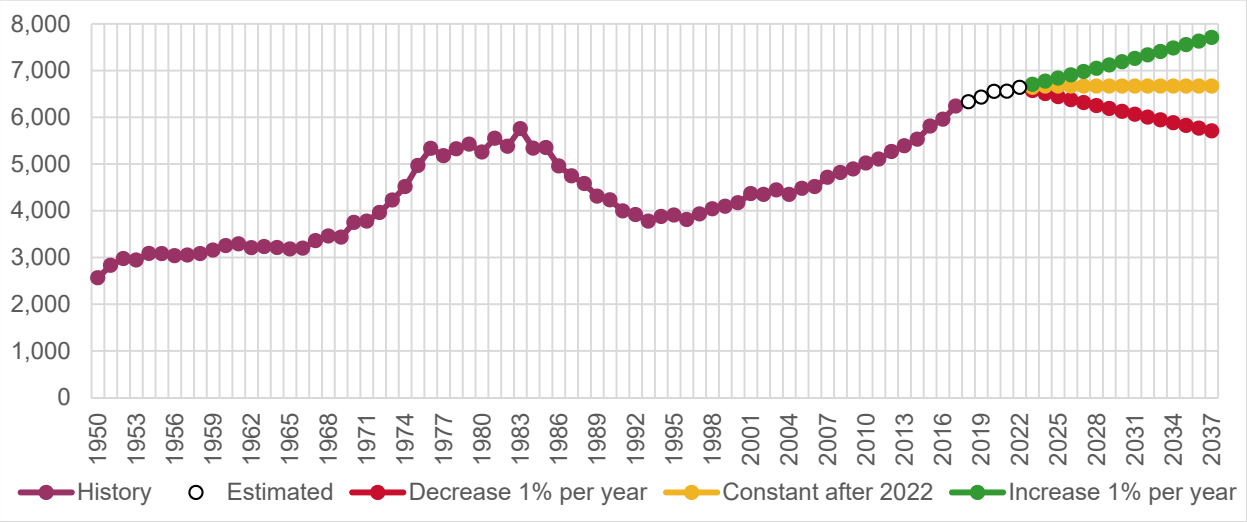
Source: ADA Health Policy Institute analysis of ADA masterfile. **Note:** Dentists counted toward inflow totals when they were on record with a degree in dentistry, a license to practice, a professionally active occupation code, and a location within the 50 states or Washington D.C.

Table 8: Historical Dentist Inflows, 2012-2017

	U.S. Dental School Graduates	Foreign-trained Dentists	Relicensed Dentists	Dentists Returned from Retirement	Total
Age under 35	23,710	753	3	1	24,467
Age 35 - 44	3,785	976	265	3	5,029
Age 45 - 54	322	619	455	19	1,415
Age 55 - 64	36	234	420	33	723
Age 65 - 74	14	91	171	32	308
Age 75 - 84	2	16	36	13	67
Age 85 and older	2	2	7	2	13
Total	27,871	2,691	1,357	103	32,022

Source: ADA Health Policy Institute analysis of ADA masterfile. **Note:** Dentists counted toward inflow totals when they were on record with a degree in dentistry, a license to practice, a professionally active occupation code, and a location within the 50 states or Washington D.C.

Figure 6: U.S. Dental School Graduates per Year, Historical, Estimated, and Three Inflow Assumptions



Sources: ADA Health Policy Institute Survey of Dental Education, ADA Health Policy Institute estimates and assumptions. **Notes:** Data for years 1950-2017 are historical. Estimates for 2018-2022 assume that all dental schools in operation in 2018 will maintain current or expected levels of graduates per year until 2022. Data points after 2022 are assumptions about future numbers of U.S. dental school graduates.

Table 9: Excerpt from Workforce Model Projection, 2017-2022, for Baseline Scenario (Unadjusted)

	Column A	Column B	Column C	Column D	Column E	Column F	Sum of Columns D, E, F
	Profes-sionally active dentists, 2017	Assumed five-year outflow rate	Apply five-year outflow rate	Apply aging logic to Column C to yield 2022 age distribution	Inflow of new U.S. graduates	Inflow of foreign-trained, relicensed, & unretired dentists	Profes-sionally active dentists, 2022
Age under 35	32,296	2.7%	31,422	8,798	26,632	707	36,137
Age 35 - 44	46,165	2.7%	44,901	45,075	4,256	1,258	50,588
Age 45 - 54	42,005	4.3%	40,208	41,348	407	819	42,575
Age 55 - 64	46,591	16.4%	38,929	44,278	0	602	44,880
Age 65 - 74	26,519	41.8%	15,446	27,082	0	374	27,456
Age 75 - 84	4,534	62.4%	1,705	5,655	0	88	5,743
Age 85 and older	407	83.6%	67	442	0	12	453
Total	198,517		172,679	172,679	31,294	3,860	207,833

Sources: ADA Health Policy Institute analysis of ADA masterfile; ADA Survey of Dental Education. **Notes**: Data for 2017 are based on the ADA masterfile. Results after 2017 are projected. Totals in the projection may not appear to match the sum of subgroups due to the rounding of fractional numbers produced by the model. Assumes (1) retirement rates over the next 20 years correspond to historical patterns under typical U.S. business cycles and (2) the annual number of U.S. dental school graduates will increase through 2022 and then remain constant. Outflow rate in Column B is the percentage of dentists who had retired, whose license had lapsed, or who were deceased.

Table 10: Historical and Projected Female Share of U.S. Dentist Workforce

	2002	2007	2012	2017	2022	2027	2032	2037
Age under 35	34.2%	41.2%	46.7%	48.8%	50.0%	50.0%	50.0%	50.0%
Age 35 - 44	26.7%	34.0%	37.4%	42.0%	47.2%	49.2%	50.0%	50.0%
Age 45 - 54	13.2%	20.8%	28.8%	34.9%	38.1%	42.8%	47.4%	49.6%
Age 55 - 64	3.8%	7.6%	13.9%	21.0%	28.8%	34.9%	38.1%	42.8%
Age 65 - 74	2.0%	2.9%	4.5%	8.3%	15.3%	22.2%	30.3%	35.7%
Age 75 and older	1.7%	1.7%	2.0%	3.6%	5.4%	10.9%	18.1%	25.6%
All ages	17.0%	21.9%	26.2%	31.0%	36.4%	40.5%	43.7%	46.0%

Source: ADA Health Policy Institute analysis of ADA masterfile. **Notes**: Data for 2002-2017 are historical. Results after 2017 are projected and assume that the female share will level off at 50% for each age cohort.

Table 11: Dentist Hours Worked by Dentist Gender and Age Group

	Average Annual Hours Worked		Indexed to Male, Age under 35	
	Male	Female	Male	Female
Age under 35	1,816.1	1,596.9	1.000	0.879
Age 35 – 44	1,821.9	1,550.9	1.003	0.854
Age 45 – 54	1,772.7	1,599.5	0.976	0.881
Age 55 – 64	1,692.0	1,554.4	0.932	0.856
Age 65 – 74	1,442.6	1,437.4	0.794	0.791
Age 75 and older	1,207.1	903.2	0.665	0.497

Source: ADA Health Policy Institute, 2007-2016 results from the Survey of Dental Practice.

Table 12: Patient Visits per Week (Excluding Hygienist Visits) by Dentist Gender and Age Group

	Average Patient Visits Per Week (Excluding Hygienist Visits)		Indexed to Male, Age under 35	
	Male	Female	Male	Female
Age under 35	62.9	51.3	1.000	0.816
Age 35 – 44	62.9	50.7	1.000	0.806
Age 45 – 54	59.2	49.1	0.941	0.781
Age 55 – 64	52.8	44.8	0.839	0.712
Age 65 – 74	45.7	38.9	0.727	0.618
Age 75 and older	34.3	19.8	0.545	0.315

Source: ADA Health Policy Institute, 2007-2016 results from the Survey of Dental Practice.

Data & Methods

Data Sources and Methodological Approach

We used five data sources in our analysis. The American Dental Association (ADA) masterfile is a database that contains the most up-to-date information on dentists, practicing and non-practicing, in the United States. It is updated through a variety of methods including reconciliation with state licensure databases, death records, and various surveys and censuses of dentists carried out by the ADA. We used the masterfile's annual archived datasets from 2003 through 2017 to gather historical information on the dentist population profile, including dentists' ages, dental school graduation years, licensure status, practice location, retirement dates, and deceased dates. This provides us with a "snapshot" for each of our study years. In addition, through various unique identifiers, we were able to track critical information for each dentist over time.

To calculate historical measures of dentists per 100,000 population, we used U.S. Census Bureau population counts.[13,14] To calculate future estimates of dentists per 100,000 population, we combined our future dentist supply modeling results with the U.S. Census Bureau's national population projections.[15]

We relied on the ADA's Survey of Dental Education for historical data on the number of graduates and current enrollment of U.S. dental schools.[16]

To gauge the variation in dentists' working hours and number of patient visits, we used the ADA's Survey of Dental Practice results from 2007 through 2016.

We used the "U.S. Business Cycle Expansions and Contractions" table from the National Bureau of Economic Research for information on the recent recession and the average duration of business cycles.

The model counts professionally active, licensed dentists in all 50 states and Washington D.C. with these occupation codes in the ADA masterfile: private practice (full or part-time), dental school faculty/staff, armed forces, other federal services (i.e., Veterans Affairs, Public Health Service, Federally Qualified Health Centers), state or local government employee, hospital staff, graduate student/intern/resident, or other health/dental organization staff member.

The workforce projection model uses historical trends in inflows of dentists to and outflows of dentists from the workforce to inform various assumptions about future inflows and outflows. We defined three types of outflows of dentists: (1) those who retired, (2) those whose license expired, and (3) those who died before retirement. We do not have data on dentists who migrate from the United States to other countries, but we expect most of these cases entail a license expiration that is accounted for in our data.

We defined four types of inflows of dentists: (1) new U.S. dental school graduates who became professionally active in the U.S., (2) foreign-trained dentists who became professionally active in the U.S., (3) dentists who reactivated an expired license, and (4) dentists who returned from retirement to the workforce.

We analyzed seven age groups of dentists separately to capture important differences in behaviors across the life cycle (e.g., propensity to graduate or retire). The age groups are: under 35, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, and 85 to 99.

Outflow History and the Business Cycle

We updated the outflows part of the model by assuming a relationship between outflows and business cycles, meaning a dentist's decision to retire

may be influenced by the presence or absence of an economic downturn.

We calculated outflows as the proportion of dentists per age group who left the workforce over a five-year period. For example, for dentists in the workforce who were aged 55 to 64 in 2012, we calculated the proportion who were retired in 2017. This provided a retirement rate for the 55 to 64 age group for the period 2012-2017. We also calculated the proportions who were deceased or whose license was expired in 2017.

We computed total outflow rates as the combined shares of dentists who had retired, whose license had lapsed, or who were deceased. Table 4 and Figures 3 and 4 display the total five-year outflow rates per age group for years ending 2007-2017.[17]

When examining historical outflow trends, we focused on dentists aged 55 and older; they account for the majority of dentists who leave the workforce in a five-year period. As seen in Table 4 and Figure 4, outflow rates for dentists aged 65 and older declined from 49 percent to 36 percent (2007-2012) and have increased to about 45 percent since then. Outflow rates for ages 55 to 64 fluctuated similarly within a narrower range.

The low outflow rates in 2012 occurred during a period following an economic downturn. The National Bureau of Economic Research determined that an 18-month recession ended in June 2009.[18] The stock market had declined from its 2007 high, reached a trough in 2009, and although recovering in 2012, was still below its peak.[19] The gross domestic product per capita (inflation-adjusted) had declined from its 2007 high, reached a trough in 2009, and in 2012 had not yet regained the level of its previous peak.[20]

Why were fewer older dentists leaving the profession in 2012 after the downturn? It is reasonable to assume that some postponed retirement. Retirement funds may have decreased in value and average general dentist income (inflation-adjusted) was declining from a 2005 peak.[20]

Calculation of Outflows, 2017-2022

Given the variance of dentists' likelihood to retire before, during and after the recent recession, the size of the dentist workforce in 2022 could also vary, depending on whether there is another economic downturn before then.

Therefore, we designed one assumption of outflow percentages to simulate the effects of an economic downturn (either a recession or a substantial decline in the stock market) before end-of-year 2022. For this, we selected outflow percentages from 2011, a year with decreased outflows but not as extreme as those in 2012 or 2013. We assumed that if there is a downturn before 2022, it will not be as severe as the last one.

We designed a second assumption of outflow percentages to represent the higher number of retirements expected if there were no economic downturn before end-of-year 2022. We selected these percentages, per age group, as either the average of those from 2007 and 2017, or simply those from 2007, as being likely continuations of the trends graphed in Figures 3 and 4.

Calculation of Outflows, 2022-2037

We used a different approach to estimate long-term outflow percentages for the 15 years after 2022. First, to understand how prevalent recessions are over the long term, we consulted the "U.S. Business Cycle Expansions and Contractions" table released by the National Bureau of Economic Research,[18] excerpted in Table 5.

The table states that from 1945 to 2009, there were 11 business cycles, each with a period of expansion and contraction. The average business cycle lasted 69.5

months and included an economic contraction (recession) of 11.1 months average duration, or 16 percent of the business cycle.

We therefore assumed that for the years 2022-2037, 16 percent of the period will be affected by a recession (specific years unknown). For this period, we calculated outflow percentages, by dentist age group, weighted 16 percent by historical outflow percentages influenced by the recent recession and weighted 84 percent by historical outflow percentages that occurred outside of the recent recession. We called these the "average business cycle" outflow percentages.

Calculation of Outflows, Baseline Assumption, 2017-2037

As described earlier, for the period 2017-2022, we created two outflow assumptions to represent the presence or absence of an economic downturn by end-of-year 2022. But for purposes of our baseline (or most likely) assumption, we applied the "average business cycle" outflow percentages to 2017-2022. This freed us from having to predict whether or not there will be an economic downturn before end-of-year 2022.

To summarize our three outflow assumptions for 2017-2037, they all applied "average business cycle" outflow percentages to the years 2022-2037. Up until 2022, one assumption is that there will be an economic downturn, a second assumption is that there will not be an economic downturn, and the third assumption applies the "average business cycle" percentages to the period 2017-2022. This third assumption is our baseline scenario. We display these three sets of outflow assumptions in Table 6.

Figure 5 compares the effects of our three outflow assumptions while holding our inflow assumption constant. Assuming an economic downturn will occur by 2022, we expect older dentists will be more likely to stay in the workforce because some "can't afford to retire," thus boosting the number of active dentists per capita. When we assume no economic downturn occurring by 2022, we expect dentists to retire in greater numbers, reducing the growth rate of dentists per capita in the short term. Our third, or baseline, assumption uses the "average business cycle" outflows applied to 2017-2022 as well as beyond 2022 and generates a trend line falling between the first two assumptions.

Calculation of Inflows

We updated the inflows analysis part of the model by recognizing that, on average, 3.7 percent of new U.S. dental school graduates will not achieve "professionally active" status long enough to be counted in the model. This group includes dentists who work in U.S. territories or the armed forces overseas, those who move to other countries, those who find U.S. employment that does not require a dentist license, and those who retire or die early.

We analyzed historical data on inflows for the periods 2007-2012 and 2012-2017 (Tables 7 and 8). We also estimated the number of U.S. dental school graduates from 2018 through 2022 based on known enrollment and expected attrition of dental school students. We incorporated the estimates of 2018-2022 graduates into all scenarios; we assumed that all dental schools in operation this year will maintain current or expected levels of graduates per year at least until 2022.

We developed three scenarios for the future inflows of dentists into the workforce based on three assumptions for the number of future graduates from 2022 to 2037. The medium scenario assumed that after 2022, the annual number of dental school graduates would remain constant at the level estimated for 2022. The high and low scenarios assumed that after 2022, the annual number of graduates would increase or decrease, respectively, at the rate of 1 percent per

year. Figure 6 displays both historical and future numbers of graduates per year under these three assumptions.

We generated future assumptions of inflows based on these high, medium and low numbers of new graduates joining the workforce. Our overall baseline scenario assumed that the medium inflow assumption would apply, meaning the annual number of graduates would increase until 2022 and then remain constant. Our baseline choice is based on the assumption that, while we can reasonably estimate the number of graduates through 2022, uncertainty increases thereafter.

We recognize that the future number of dental school graduates is subject to intense debate and speculation. On one hand, there are dental schools that have recently opened. On the other hand, the flattening of dentist earnings in recent years[21] combined with increases in dental educational debt and reduced demand for restorative dental care could place downward pressure on the number of dental school applicants, as suggested in previous research.[5,10,22]

Historically, at least 80 percent of inflows have been new U.S. dental school graduates with remaining inflows coming from foreign-trained dentists, established dentists who reactivated an expired license, and dentists who came out of retirement. Tables 7 and 8 show that these smaller subsets of inflows have been a variable proportion of the total supply of dentists. Therefore, to minimize the number of scenarios under consideration, we designed the model to project this smaller subset of inflows as a constant percentage of active licensed dentists. We believe this is a reasonable assumption and our sensitivity analysis shows alternative assumptions have no relevant impact on overall results.

Combining Outflows and Inflows in the Model for Unadjusted Dentist Estimates

The model started with the 2017 active licensed dentist workforce broken down into seven age groups. We applied various assumptions for outflows per age group to calculate the number of these dentists still working in 2022. We applied aging logic based on masterfile historical patterns of how these seven age groups move from younger to older groups in a five-year period to yield an updated age distribution for 2022. To this total, we added the estimated inflows of new dental school graduates, foreign-trained dentists, and relicensed and unretired dentists by age group.

Table 9 summarizes the basic working of the model and shows results for our baseline scenario of the projected dentist workforce (unadjusted) in 2022. We repeated the process to calculate projections for 2027, 2032 and 2037.

Female Share of the Dentist Workforce

We examined the historical trends of females as a share of dental school graduates and the dentist workforce. From 1976 to 2016, the female share of U.S. dental school graduates grew dramatically from 4.6 percent to 49.1 percent.[16,23]

The increase in female dental school graduates since the 1970s affects the dentist workforce today. Among active dentists under age 35, the female share grew from 34.2 percent (2002) to 48.8 percent (2017). For active dentists aged 55 to 64, the female share grew from 3.8 percent (2002) to 21.0 percent (2017).

After analyzing the historical growth of females in all dentist age cohorts, we projected the future female share of each cohort, as summarized in Table 10. These projections assume that the female share of U.S. dental school graduates will level off at 50 percent.

We applied these projected percentages of women in the dentist workforce to our total workforce projection, yielding projections of the dentist workforce by gender and age group.

Adjusted Projections

For each dentist gender and age group, we calculated the average annual hours worked. We then calculated an index of hours worked that compared every gender and age group to male dentists under age 35: the group that typically has the highest average and the group we used as the reference group. For example, the "hours worked" index for females under age 35 was 0.879 because their average annual hours worked was 87.9 percent of the level for males under age 35 (Table 11).

We performed similar calculations for all dentist gender and age groups based on average patient visits per week, excluding hygienist visits (Table 12).

Using these indices per gender and age group as multipliers to the projection of the dentist workforce by gender and age group, we calculated the adjusted projections of dentists per 100,000 population seen in Tables 2 and 3. Both tables show the nine scenarios we selected to display a variety of combinations of assumptions of future inflows of dentists to and outflows of dentists from the workforce.

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