DATA EVALUATION AND METHODS RESEARCH

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Number 64

United States Life Tables by Dentulous or Edentulous Condition, 1971 and 1957-58

Numbers of survivors by age, sex, and dentulous or edentulous condition, and average remaining lifetime by age and sex, classified by dentulous and edentulous years. Based on data collected in household interviews in 1971 and 1957-58.

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FOREWORD

Life table techniques are very useful in the joint analysis of morbidity and mortality phenomena which can be viewed in cohort terms. Frequently, however, the available data do not satisfy the data needs specified by the life table models and assumptions are required. In this instance, we wished to estimate dentulous longevity which depends on mortality as well as on the incidence of edentulousness, the condition of having lost all of one's natural teeth. However, the mortality and morbidity statistics needed to estimate dentulous longevity were only partly available.

We were particularly interested in comparing the sexes with respect to the lengthening of their recent dentulous longevity. Morbidity data were available for two periods, 1957-58 and 1971, from the Health Interview Survey. During each period, the edentulous prevalence rate was lower for males than females, and between the two periods there was a substantial reduction in the prevalence of edentulousness for each sex. The mortality picture was somewhat different. During 1957-58 and 1971, mortality rates were lower for females than for males, and between the two periods the reductions in the mortality were less for males than for females.

This report presents selected functions of abridged edentulous life tables for 1971 and 1957-58. Life table statistics are presented for males, females, and for the combined sexes. The major findings with respect to dentulous longevity are summarized in table D on page 4 . Thus, the average remaining dentulous lifetime (average length of life without having lost all of one's natural teeth) at age 20 increased by more than 2 years between 1957-58 and 1971. During the same period, the average remaining lifetime at age 20 increased by 1 year. The average remaining dentulous lifetime was greater for females than for males during both calendar periods but the difference was greater during the latter period, indicating that females experienced greater gains than males in dentulous longevity between the calendar periods.

Calculating dentulous longevity required two kinds of data which were not available, namely, age-specific incidence rates of edentulousness and age-specific mortality rates for the edentulous and for the dentulous populations. The problems were resolved as follows. The incidence rates of edentulousness were obtained (appendix III) essentially by differencing the age-specific prevalence rates which were available from the National Health Interview Survey. (Fortunately, the prevalence rates of edentulousness increased montonically with advancing age.) With respect to the unavailable mortality data, it was assumed that dentulous and edentulous persons are

subject to the same rates. Whether or not these assumptions are viable depends somewhat on the analytical objectives. If the primary objective is to compare sex differences in the lengthening of dentulous longevity, the assumptions are probably more tolerable than if the objective is to estimate the length of dentulous life *per se*.

The principal justification for estimating dentulous longevity was methodological rather than substantive. We hope that this demonstration will stimulate applying life table techniques to other morbid conditions than edentulousness. It is noteworthy that the life table model used in this report is applicable to many kinds of morbid conditions, such as permanent impairments and chronic conditions, from which there is no chance of recovery. The mortality and morbidity statistics that would be required are not likely to be available for any of these morbid conditions, however, and it is doubtful that the assumptions that were made to overcome the problem of unavailable edentulous data would be appropriate for most other morbid conditions. Therefore, other kinds of assumptions would have to be devised.

Life table statistics presented in this report are subject to sampling errors and nonsampling errors. They are subject to sampling errors because the Health Interview Survey, the source of the edentulous prevalence rates is a sample data system. Sampling errors of the prevalence rates and procedures for calculating sampling errors of life table statistics are presented in appendix II. The life table statistics are subject to nonsampling errors including measurement errors and errors due to the unavailability of specified mortality and morbidity data on edentulousness. Although estimates of nonsampling errors are not presented in this report, there can be little doubt that they would be larger than the sampling errors.

Monroe G. Sirken, Director,
Office of Statistical Methods

CONTENTS

SYMBOLS

Data not available	- - -
Category not applicable	. . .
Quantity zero	-
Quantity more than 0 but less than 0.05	0.0
Figure does not meet standards of reliability or precision	*

UNITED STATES LIFE TABLES BY DENTULOUS OR EDENTULOUS CONDITION, 1971 AND 1957-58

T. N. E. Greville, Ph.D. *Office of Statistical Methods*

INTRODUCTION

Data on edentulousness, the condition of having lost all of one's natural teeth, have been obtained through the Health Interview Survey of the National Center for Health Statistics on two occasions, in 1957-58[1] and in 1971.[2] By combining these data with life tables for comparable periods, one can estimate the probability that a dentulous person (that is, still having at least one natural tooth) at a specified age will be still alive but edentulous at a subsequent age. One can also estimate, for a dentulous person at a stated age, the division of the average remaining years of life into dentulous and edentulous years. It is the purpose of this report to present the results of such calculations. The comparison of the results for the two time periods is of particular interest.

HISTORICAL SURVEY

In 1943, Klein[3] published life tables for teeth, based on data collected by the Committee on the Costs of Medical Care and the Public Health Service and reported by Collins.[4] The underlying data provided the number of natural teeth present in the mouth of each respondent, and the values in the tables were average numbers of teeth remaining at successive ages. Thus these were life tables for teeth, not for persons.

From a survey of all dental practitioners, Evans and Cellier[5] obtained information on all extractions performed in South Australia during a 3-week period in November 1966. From these data they estimated incidence rates of edentulousness by age and sex.

Incidence rates like those developed in the Australian study appear to be a prerequisite for constructing the kind of tables appearing in the present report. Because only prevalence rates were available (and not incidence rates), it was necessary to make certain artificial assumptions which will be described later.

Although data on prevalence of edentulousness have also been obtained from the Health Examination Survey[6] of the National Center for Health Statistics, it was preferred to utilize the data from the Health Interview Survey because they are based on a much larger sample of respondents and they also provide an interesting comparison, having been obtained on survey dates 13 years apart. Table A suggests that the findings of the Health Examination Survey are consistent with the data of the Health Interview Survey utilized in this report, even though data for exactly comparable age intervals are not available from the two surveys.

Table A. Prevalence rates of edentulousness per 100 persons from different surveys, by sex: United States

Sex	Health Interview Surveys, ages 15 and over		Health Examination Survey, ages 18-79
	1971	1957-58	1960-62
	Rate per 100 persons		
Both sexes--	15.7	18.9	18.1
Female----	16.8	20.0	19.7
Male------	14.5	17.6	16.5

INTERPRETATION OF THE TABLES

General Assumptions

It has already been stated that in order to construct the kind of tables presented in this report when only prevalence rates of edentulousness (and not incidence rates) were available, it was necessary to make certain artificial assumptions. In general terms, it was assumed that the prevalence rate of edentulousness in a given age interval in the hypothetical stationary population associated with the life table[7] is the same as in the actual sampled population, and further that age-specific mortality rates are the same for dentulous and edentulous persons. One would expect that neither assumption is in accord with actual facts. The current prevalence of edentulousness in a given cohort depends in a complicated way upon the previous history of the cohort, and it is clear from the data of the three surveys as shown in table A that the incidence of edentulousness has declined markedly in recent years. As to the second assumption, it is likely that loss of all teeth is negatively correlated with the general state of health. Therefore the values in the tables must be regarded as rough approximations.

A more technical discussion of these assumptions and detailed description of the methodology employed are found in appendix I. Appendix II concerns the sampling variability of the prevalence rates of edentulousness and the numerical quantities calculated from them. Appendix III contains a technical discussion of the incidence rates implied by the assumptions used.

Survival Rates and Transition Probabilities

Tables 1 and 2 show the number of survivors at the indicated ages in a hypothetical life-table cohort starting from 100,000 births, subdivided by dentulous and edentulous condition. Table 1 is based on 1971 prevalence rates of edentulousness from the Health Interview Survey and on 1971 life tables.[7] Table 2 is based on 1957-58 prevalence data and 1958 life tables.[8]

The following illustration will help to clarify the way in which the values in these tables may be interpreted. By table 1, the proportion of females alive at age 25 who survive to age 55 is $89,291 \div 97,081 = .91976$. Under the assumption previously stated, this value applies equally to dentulous and edentulous females. Therefore the number of survivors to 55 of the 1,631 who were already edentulous at 25 is $1,631 \times .91976 = 1,500$. The remaining $21,894 - 1,500 = 20,394$ edentulous females at age 55 are survivors of the 95,450 who were dentulous at 25. Thus if we choose to interpret such ratios as probabilities, the probability that

Table B. Indicated probabilities that a dentulous person at age 20 will be alive but edentulous at ages shown by sex, based on 1971 prevalence rates and 1971 life tables: United States

Age	Both sexes	Female	Male
	Probability		
45 years--------	.115	.128	.103
55 years--------	.210	.222	.198
65 years--------	.283	.308	.257
75 years--------	.273	.344	.205

Table C. Indicated probabilities that a dentulous person at age 20 will be alive but edentulous at ages shown by sex, based on 1957-58 prevalence rates and 1958 life tables: United States

Age	Both sexes	Female	Male
	Probability		
45 years	.145	.152	.136
55 years	.261	.281	.239
65 years	.341	.391	.293
75 years	.293	.372	.223

a dentulous female aged 25 will be alive but edentulous at 55 is 20,394 ÷ 95,450 = .214.

Tables B and C show the indicated probabilities, on the basis of 1971 and 1957-58 data, respectively, that a dentulous person at age 20 will be alive but edentulous at the ages shown.

The probability that a person now dentulous at a given age will survive to a subsequent age but become edentulous may be regarded as the product of two probabilities: The probability of survival and the probability of being edentulous if alive at the subsequent age. In every instance the survival rate for females is greater than for males, and in all but a few cases the prevalence rate of edentulousness is also greater for females. Consequently, every probability for females in tables B and C is greater than the corresponding value for males.

In general, up to age 65 the increase with age in the prevalence rates of edentulousness is more rapid than the decrease in the survival rate from age 20, while the reverse is true between ages 65 and 75. Therefore in most instances the probabilities in tables B and C increase with advancing age up to 65 and then decline between 65 and 75. The exception in the case of females in 1971 is due to the slow decrease in survival rates even up to age 75.

On the basis of table 1, the probability that the same dentulous female at age 25 will survive to age 55 and remain dentulous is simply 67,397 ÷ 95,450 = .706.

Now, the probability that this female will survive to age 55 regardless of tooth loss is 89,291 ÷ 97,081 = .920. Clearly this must be the sum of the two probabilities that she will survive in a dentulous and an edentulous condition. Thus the probability of edentulous survival to age 55 could have been calculated more simply as .920 − .706 = .214. This is the same value previously obtained.

Expectation of Dentulous and Edentulous Life

If age-sex specific rates of mortality are the same for dentulous and edentulous persons, the same is true of the average remaining lifetime, also called the expectation of life. However, it is now possible to subdivide the average remaining lifetime of a dentulous person into the years to be spent in the dentulous and the edentulous state. The results are shown in tables 3 and 4, based on the data of 1971 and 1957-58, respectively.

It should be noted that in the computation of the average remaining years of edentulous life, those persons who never become edentulous are, in effect, credited with zero years. These figures would be much larger if only those who eventually become edentulous were included in the average.

Because of the greater prevalence rates of edentulousness for females, the proportion of edentulous years shown in tables 3 and 4 is consistently greater for females than for males in both time intervals. For each sex, this proportion is substantially less for 1971 than for 1957-58, except at the oldest ages shown.

Table D compares the total average remaining lifetime and the average remaining dentulous lifetime at selected ages, by sex, for the two time periods considered.

Table D. Average remaining lifetime and average remaining dentulous lifetime of a dentulous person by age and sex: United States, 1971 and 1957-58

Survey period and age	Total			Dentulous		
	Both sexes	Female	Male	Both sexes	Female	Male
	Average remaining lifetime in years					
1971						
20 years	53.2	56.7	49.8	42.0	43.5	40.6
30 years	43.9	47.1	40.8	33.8	35.3	32.4
40 years	34.7	37.7	31.7	26.2	27.9	24.6
50 years	26.1	28.9	23.3	19.3	20.8	17.8
60 years	18.5	20.6	16.1	14.1	15.2	12.8
70 years	12.1	13.4	10.6	9.7	10.2	9.0
1957-58						
20 years	52.2	55.2	49.4	39.7	40.4	39.1
30 years	42.8	45.6	40.2	31.2	32.0	30.3
40 years	33.6	36.2	31.1	23.5	24.2	22.7
50 years	24.9	27.3	22.7	17.5	18.1	16.9
60 years	17.3	19.1	15.6	12.6	13.3	12.0
70 years	11.1	12.1	10.1	9.1	9.3	8.7

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LIST OF DETAILED TABLES

Table 1. Survivors to stated ages by sex and dentulous or edentulous condition: United States, 1971

Sex and age	Total	Dentulous	Edentulous
	Number		
Both sexes			
20 years	96,847	96,527	320
25 years	96,146	94,723	1,423
30 years	95,462	91,892	3,570
35 years	94,650	88,450	6,200
40 years	93,499	84,832	8,667
45 years	91,781	80,336	11,445
50 years	89,234	73,716	15,518
55 years	85,439	64,874	20,565
60 years	80,000	55,088	24,912
65 years	72,326	44,806	27,520
70 years	62,482	33,834	28,648
75 years	49,841	23,306	26,535
Female			
20 years	97,440	97,128	312
25 years	97,081	95,450	1,631
30 years	96,664	92,672	3,992
35 years	96,096	89,196	6,900
40 years	95,240	85,392	9,848
45 years	93,933	81,243	12,690
50 years	92,035	75,432	16,603
55 years	89,291	67,397	21,894
60 years	85,469	58,692	26,777
65 years	79,951	49,777	30,174
70 years	72,291	39,066	33,225
75 years	61,161	27,565	33,596
Male			
20 years	96,280	95,943	337
25 years	95,229	94,020	1,209
30 years	94,280	91,131	3,149
35 years	93,223	87,769	5,454
40 years	91,776	84,333	7,443
45 years	89,642	79,459	10,183
50 years	86,435	72,009	14,426
55 years	81,582	62,345	19,237
60 years	74,555	51,495	23,060
65 years	64,812	39,911	24,901
70 years	52,974	28,791	24,183
75 years	39,004	19,202	19,802

Table 2. Survivors to stated ages by sex and dentulous or edentulous condition: United States, 1957-58

Sex and age	Total	Dentulous	Edentulous
	Number		
Both sexes			
20 years	95,991	95,127	864
25 years	95,400	93,254	2,146
30 years	94,785	91,373	3,412
35 years	94,003	87,799	6,204
40 years	92,900	83,982	8,918
45 years	91,191	76,600	14,591
50 years	88,578	68,737	19,841
55 years	84,524	58,955	25,569
60 years	78,792	48,772	30,020
65 years	70,791	37,696	33,095
70 years	59,556	26,562	32,994
75 years	46,178	17,848	28,330
Female			
20 years	96,615	95,745	870
25 years	96,280	93,680	2,600
30 years	95,848	91,535	4,313
35 years	95,243	88,195	7,048
40 years	94,373	84,653	9,720
45 years	93,073	77,669	15,404
50 years	91,123	70,347	20,776
55 years	88,220	60,475	27,745
60 years	84,080	50,364	33,716
65 years	78,029	39,912	38,117
70 years	68,708	29,132	39,576
75 years	56,214	20,068	36,146
Male			
20 years	95,393	94,534	859
25 years	94,537	92,883	1,654
30 years	93,736	91,299	2,437
35 years	92,772	87,484	5,288
40 years	91,431	83,385	8,046
45 years	89,305	75,597	13,708
50 years	86,034	67,193	18,841
55 years	80,744	57,409	23,335
60 years	73,528	47,131	26,397
65 years	63,767	35,486	28,281
70 years	50,985	24,065	26,920
75 years	37,115	15,737	21,378

Table 3. Average remaining lifetime of a dentulous person, average remaining dentulous and edentulous years, and proportion of edentulous years, by sex and age: United States, 1971

Sex and age	Total	Dentulous	Edentulous	Proportion of edentulous years
	Average remaining lifetime in years			
Both sexes				
20 years	53.2	42.0	11.2	.21
25 years	48.6	37.8	10.8	.22
30 years	43.9	33.8	10.1	.23
35 years	39.3	30.0	9.3	.24
40 years	34.7	26.2	8.5	.24
45 years	30.3	22.5	7.8	.26
50 years	26.1	19.3	6.8	.26
55 years	22.1	16.6	5.5	.25
60 years	18.5	14.1	4.4	.24
65 years	15.1	11.7	3.4	.23
70 years	12.1	9.7	2.4	.20
75 years	9.5	8.0	1.5	.16
Female				
20 years	56.7	43.5	13.2	.23
25 years	51.9	39.2	12.7	.24
30 years	47.1	35.3	11.8	.25
35 years	42.4	31.6	10.8	.25
40 years	37.7	27.9	9.8	.26
45 years	33.2	24.1	9.1	.27
50 years	28.9	20.8	8.1	.28
55 years	24.7	17.9	6.8	.28
60 years	20.6	15.2	5.4	.26
65 years	16.9	12.5	4.4	.26
70 years	13.4	10.2	3.2	.24
75 years	10.4	8.5	1.9	.18
Male				
20 years	49.8	40.6	9.2	.18
25 years	45.3	36.3	9.0	.20
30 years	40.8	32.4	8.4	.21
35 years	36.2	28.5	7.7	.21
40 years	31.7	24.6	7.1	.22
45 years	27.4	20.9	6.5	.24
50 years	23.3	17.8	5.5	.24
55 years	19.5	15.1	4.4	.23
60 years	16.1	12.8	3.3	.20
65 years	13.2	10.8	2.4	.18
70 years	10.6	9.0	1.6	.15
75 years	8.4	7.4	1.0	.12

Table 4. Average remaining lifetime of a dentulous person, average remaining dentulous and edentulous years, and proportion of edentulous years, by sex and age: United States, 1957-58

Sex and age	Total	Dentulous	Edentulous	Proportion of edentulous years
	Average remaining lifetime in years			
Both sexes				
20 years	52.2	39.7	12.5	.24
25 years	47.5	35.5	12.0	.25
30 years	42.8	31.2	11.6	.27
35 years	38.1	27.3	10.8	.28
40 years	33.6	23.5	10.1	.30
45 years	29.1	20.5	8.6	.30
50 years	24.9	17.5	7.4	.30
55 years	21.0	15.0	6.0	.29
60 years	17.3	12.6	4.7	.27
65 years	14.0	10.6	3.4	.24
70 years	11.1	9.1	2.0	.18
75 years	8.6	7.3	1.3	.15
Female				
20 years	55.2	40.4	14.8	.27
25 years	50.3	36.2	14.1	.28
30 years	45.6	32.0	13.6	.30
35 years	40.8	28.1	12.7	.31
40 years	36.2	24.2	12.0	.33
45 years	31.6	21.2	10.4	.33
50 years	27.3	18.1	9.2	.34
55 years	23.1	15.7	7.4	.32
60 years	19.1	13.3	5.8	.30
65 years	15.4	11.1	4.3	.28
70 years	12.1	9.3	2.8	.23
75 years	9.2	7.5	1.7	.18
Male				
20 years	49.4	39.1	10.3	.21
25 years	44.9	34.7	10.2	.23
30 years	40.2	30.3	9.9	.25
35 years	35.6	26.5	9.1	.26
40 years	31.1	22.7	8.4	.27
45 years	26.8	19.8	7.0	.26
50 years	22.7	16.9	5.8	.26
55 years	19.0	14.4	4.6	.24
60 years	15.6	12.0	3.6	.23
65 years	12.6	10.1	2.5	.20
70 years	10.1	8.7	1.4	.14
75 years	8.0	7.1	0.9	.11

APPENDIX I

TECHNICAL NOTES ON METHODOLOGY

It is the purpose of this appendix to describe the methodology used in the construction of the detailed tables.

Source of Data

Data underlying this report are prevalence rates of edentulousness by sex and age for 1971 and 1957-58 obtained in the Health Interview Survey[2, 1] and abridged life tables[7, 8] for 1971 and 1958. The earlier prevalence rates of edentulousness cover the period July 1957-June 1958, while the annual abridged life tables are each based on the data of a single calendar year. A decision was made on a purely arbitrary basis to use the 1958 (rather than 1957) life tables. Differences between the life tables of the two years are negligible.

The prevalence rates utilized in this report are shown (along with other data) in tables I and II.

Calculation of Numbers of Survivors

It was assumed in the calculations that the prevalence rates by sex and age observed in the sample apply equally to the life table population. Prevalence rates not directly available from tables I and II were estimated by straight-line interpolation. In performing this interpolation, each of the prevalence rates in tables I and II (except those for the terminal age intervals) was associated with the midpoint of the interval of exact ages to which the rate applies. For example, the age interval 45-49 (in completed years) comprises all exact ages between 45 and 50 and the midpoint is age 47.5. The prevalence rates in 1971 for exact age 50 (needed in the calculation of edentulous survivors) was estimated by taking the arithmetic mean of those for age intervals 45-49 and 50-54. Such prevalence rates were estimated for quinquennial exact ages from 20 to 75, inclusive.

Prevalence rates of 1957-58 were available from the survey only for the decennial age intervals shown in table II. Rates for quinquennial age intervals (needed subsequently in the calculation of average remaining lifetime) were estimated by straight-line interpolation. For example, the rate for the age interval 45-49 (midpoint 47.5) for females was estimated from those for intervals 35-44 (midpoint 40) and 45-54 (midpoint 50) by the formula

$$\frac{50-47.5}{50-40}\ (10.3)\ +\ \frac{47.5-40}{50-40}\ (22.8)$$

$$=\ .25\ \times\ 10.3\ +\ .75\ \times\ 22.8\ =\ 19.675.$$

In the calculation of prevalence rates of 1957-58 for exact age 75, the age interval 75 and over was treated as being 75-84 (with midpoint at 80).

Values of ℓ_x (number of survivors to age x of 100,000 live births) were taken directly from the respective life tables. They were not standardized to produce a round number at age 20. The number of edentulous survivors at age x was obtained by multiplying ℓ_x by the appropriate prevalence rate. The number of dentulous survivors is the total number minus the number of edentulous survivors.

Table I. Estimated number and rate per 1,000 population of edentulous persons by sex and age: United States, 1971

Sex and age	Total population	Edentulous persons	
		Number	Rate per 1,000 population
Both sexes			
15-19 years	19,000,939	[1]16,210	[1]0.9
20-24 years	16,255,280	93,392	5.7
25-29 years	13,763,688	327,978	23.8
30-34 years	11,418,812	582,457	51.0
35-39 years	10,734,663	857,640	79.9
40-44 years	11,510,922	1,212,850	105.4
45-49 years	12,094,428	1,740,707	143.9
50-54 years	11,151,614	2,274,141	203.9
55-59 years	10,133,703	2,812,180	277.5
60-64 years	8,383,916	2,894,655	345.3
65-69 years	6,881,047	2,860,527	415.7
70-74 years	5,163,246	2,587,790	501.2
75-79 years	3,835,244	2,161,329	563.5
80-84 years	2,243,037	1,390,607	620.0
85-89 years	922,063	624,327	677.1
85 years and over	1,226,544	819,008	667.7
Female			
15-19 years	9,555,961	[1]7,414	[1]0.8
20-24 years	8,795,072	48,685	[1]5.5
25-29 years	7,110,929	198,880	28.0
30-34 years	5,925,961	322,774	54.5
35-39 years	5,648,021	502,993	89.1
40-44 years	5,901,517	693,769	117.6
45-49 years	6,285,786	958,766	152.5
50-54 years	5,823,709	1,213,166	208.3
55-59 years	5,309,179	1,497,893	282.1
60-64 years	4,513,193	1,554,982	344.5
65-69 years	3,762,027	1,543,511	410.3
70-74 years	2,983,182	1,517,950	508.8
75-79 years	2,290,609	1,350,875	589.7
80-84 years	1,369,923	864,271	630.9
85-89 years	554,103	392,203	707.8
85 years and over	752,611	527,841	701.3
Male			
15-19 years	9,444,978	[1]8,796	[1]0.9
20-24 years	7,460,208	44,707	[1]6.0
25-29 years	6,652,759	129,098	19.4
30-34 years	5,492,851	259,683	47.3
35-39 years	5,086,642	354,647	69.7
40-44 years	5,609,405	519,081	92.5
45-49 years	5,808,642	781,941	134.6
50-54 years	5,327,905	1,060,975	199.1
55-59 years	4,824,524	1,314,287	272.4
60-64 years	3,870,723	1,339,673	346.1
65-69 years	3,119,020	1,317,016	422.3
70-74 years	2,180,064	1,069,840	490.7
75-79 years	1,544,635	810,454	524.7
80-84 years	873,114	526,336	602.8
85-89 years	367,960	232,124	630.8
85 years and over	473,933	291,167	614.4

[1]Relative standard error is more than 30 percent.

Table II. Estimated number and percent of edentulous persons by sex and age: United States, July 1957-June 1958

Sex and age	Total population in thousands	Edentulous persons	
		Number in thousands	Rate per 100 population
Both sexes			
15-24 years	21,093	194	0.9
25-34 years	22,738	812	3.6
35-44 years	22,918	2,196	9.6
45-54 years	19,639	4,390	22.4
55-64 years	14,831	5,647	38.1
65-74 years	9,627	5,329	55.4
75 years and over	4,886	3,287	67.3
Female			
15-24 years	11,292	102	0.9
25-34 years	11,880	535	4.5
35-44 years	11,892	1,228	10.3
45-54 years	10,047	2,287	22.8
55-64 years	7,685	3,082	40.1
65-74 years	5,116	2,947	57.6
75 years and over	2,755	1,957	71.0
Male			
15-24 years	9,801	91	0.9
25-34 years	10,859	277	2.6
35-44 years	11,026	968	8.8
45-54 years	9,592	2,103	21.9
55-64 years	7,147	2,565	35.9
65-74 years	4,511	2,383	52.8
75 years and over	2,131	1,330	62.4

Calculation of Average Remaining Lifetime

Values of ${}_5L_x$ (number between exact ages x and $x + 5$ in the stationary population associated with the life tables) were subdivided into dentulous and edentulous persons by applying appropriate prevalence rates. These values are not shown in this report. This process is analogous to the subdivision of ℓ_x values described in the preceding section. For the 1971 data the process was carried up to age 85. The corresponding values for the terminal age intervals ($T_{85} = {}_\infty L_{85}$ for the 1971 data and $T_{75} = {}_\infty L_{75}$ for the 1957-58 data) were similarly subdivided. It will be convenient to denote the dentulous and edentulous components by superscripts (d) and (e).

For each quinquennial age x from 20 to 75, a value of $T_x^{(d)}$ (the number of dentulous persons in the stationary population at ages x and above) was obtained by adding to ${}_5L_x^{(d)}$ the corresponding values for all subsequent age intervals, including the terminal interval. In other words, the $T_x^{(d)}$ column on the worksheet is obtained by accumulating the ${}_5L_x^{(d)}$ column from the bottom up.

The average remaining dentulous lifetime of a dentulous person aged x, which is denoted by $\mathring{e}_x^{(d)}$, was obtained by the formula

$$\mathring{e}_x^{(d)} = T_x^{(d)} / \ell_x^{(d)}.$$

The justification for this formula is that the dentulous part of the cohort is a "closed" group in

the sense that a person who becomes edentulous will never again be dentulous.

The second major assumption made in this report is that age-sex-specific mortality rates are the same for dentulous and edentulous persons. This implies that the average remaining lifetime at age x is the same for dentulous and edentulous persons. In other words, the average remaining lifetime for dentulous persons is the same as that for all persons (of the given age and sex). Thus if $\overset{\circ}{e}_x^{(de)}$ denotes the average remaining edentulous lifetime of a dentulous person aged x this is taken to be

$$\overset{\circ}{e}_x^{(de)} = \overset{\circ}{e}_x - \overset{\circ}{e}_x^{(d)}.$$

Values of $\overset{\circ}{e}_x$ were taken from the appropriate life tables.[7, 8] Tables 3 and 4 show also values of $\overset{\circ}{e}_x^{(d)}$ and $\overset{\circ}{e}_x^{(de)}$ which were estimated in the manner just described.

APPENDIX II
RELIABILITY OF ESTIMATES

Standard Errors of Prevalence Rates

Since the numerical quantities presented in this report are based on a sample, they differ somewhat from the values that would have been obtained if prevalence rates of edentulousness had been derived from a complete census. The tables shown in appendix I and the chart included in this appendix are designed to provide measures of this sampling variability. They do not include estimates of any biases that might be present in the data.

Tables I and II show, for each sex-age category, the estimated number of edentulous persons, as well as the total population (according to estimates of the U.S. Bureau of the Census) and the prevalence rate. Figure I is intended to assist the reader in determining standard errors of the prevalence rates. The values so obtained are, of course, estimates of the standard errors, but to avoid excess verbiage, they will henceforth be referred to merely as "standard errors." In order to use this graph, one must find in the appropriate table (table I or II) the estimated number of edentulous persons corresponding to the prevalence rate in question. This estimated number must be located on the base line (horizontal axis) of the figure. The corresponding reading on the vertical axis is the relative standard error (in percent) of this estimated number and also of the corresponding prevalence rate. For example, consider the prevalence rate of 152.5 per 1,000 population for females aged 45-49 in 1971. By table I the corresponding estimate of the number of edentulous persons is 958,766. The ordinate of the graph in figure I corresponding to an abscissa of 958,766 is approximately 5.6 percent, or .056, which is therefore the relative standard error of the prevalence rate in question.

The standard error is primarily a measure of sampling variability, that is, the variations that might occur by chance because only a sample of the population is surveyed. The chances are about 68 out of 100 that an estimate from the sample would differ from the value obtained in a complete census by less than the standard error. The chances are about 95 out of 100 that the difference would be less than twice the standard error, and about 99 out of 100 that it would be less than 2½ times as large.

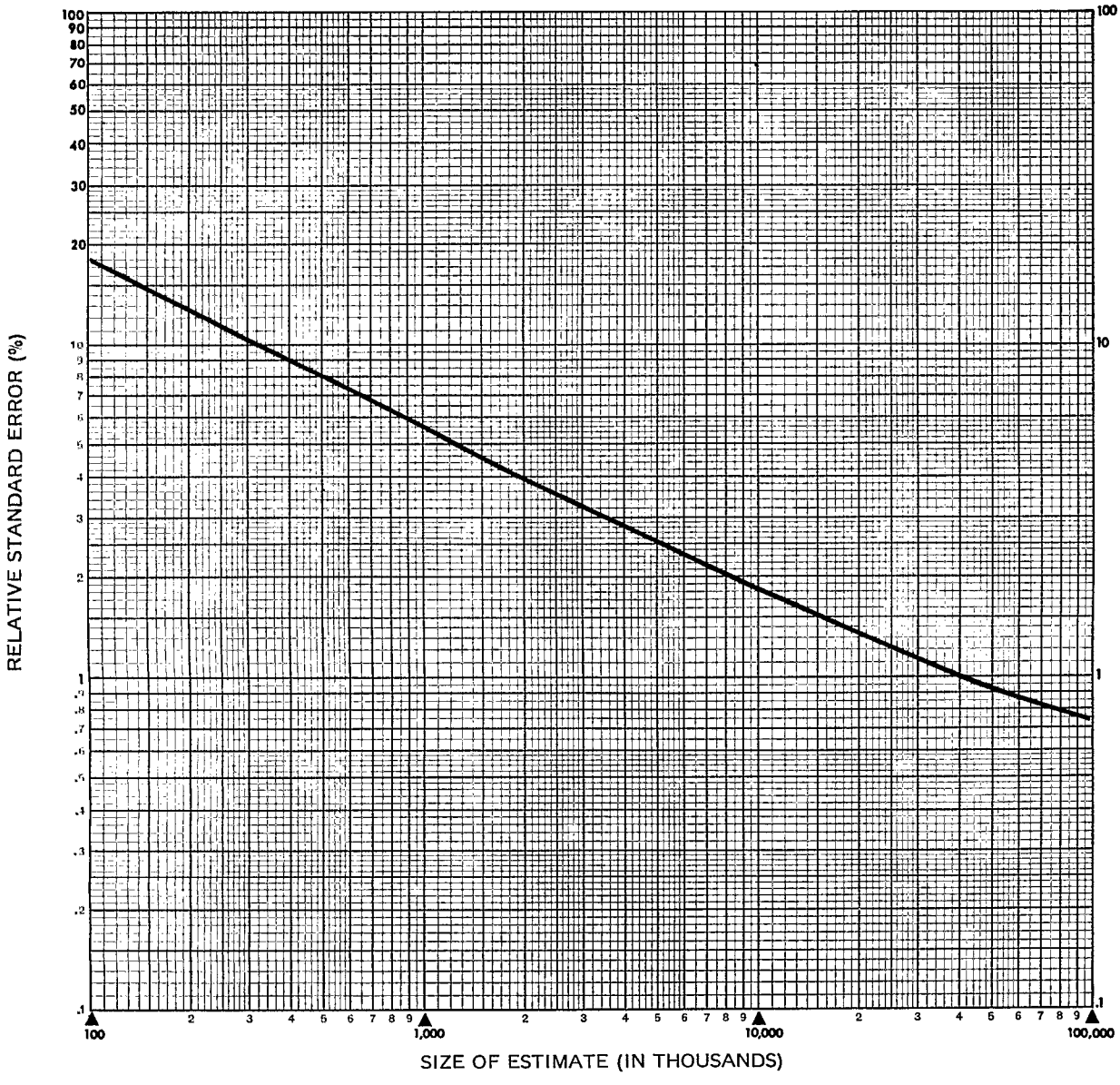
As a further illustration, observe that the only instances in tables I and II in which prevalence rates for females do not exceed the corresponding rates for males (with the exception of some marginal cases at ages under 25) occur at ages 60-64 and 65-69 in 1971. One may ask whether these two exceptions to the general rule could reasonably be ascribed to sampling variability.

The following figures extracted from table I show the number of edentulous persons of each sex in each of the two age intervals in question:

	Female	*Male*
60-64	1,544,982	1,339,673
65-69	1,543,511	1,317,016

Entering the chart in figure 1 with these numbers, one can read the corresponding relative

Figure I. Relative standard errors of numbers of edentulous persons and corresponding prevalence rates.



Example of use of chart: An estimate of 1,000,000 edentulous persons (on scale at bottom of chart) has a relative standard error of 5.6 percent, or a standard error of 56,000 (5.6 percent of 1,000,000).

standard errors as follows:

	Female	*Male*
	Percent	
60-64	2.4	3.0
65-69	2.4	3.2

These are also the relative standard errors of the corresponding prevalence rates. Consequently, the absolute standard errors of the prevalence rates per 1,000 population are:

	Female	*Male*
	Percent	
60-64	8.3	10.4
65-69	9.8	13.5

If covariance is ignored, the standard error of the female minus male difference is the square root of the sum of the squares of the standard errors for females and males separately. The differences in prevalence rates and the corresponding standard errors are as follows:

	Difference in prevalence rates	*Standard error of difference*
	Percent	
60-64	1.6	13.3
65-69	12.0	16.7

It is clear that the larger prevalence rates for males in these two instances could reasonably be ascribed to sampling variation.

Standard Errors of Numbers of Survivors

The numbers of edentulous survivors shown in table 1 are obtained by multiplying life-table values for the United States population by prevalence rates of edentulousness. In most instances, the prevalence rate in question is obtained by straight-line interpolation between two consecutive tabular prevalence rates. If the latter two rates are denoted by $\hat{\pi}_1$ and $\hat{\pi}_2$ and the interpolated rate by $\hat{\pi}$ (where the circumflex accent denotes that the rates are estimates based on a sample, while its absence denotes the underlying true rates), and if

$$\hat{\pi} = t\hat{\pi}_1 + (1-t)\hat{\pi}_2,$$

and further if ρ_1 and ρ_2 denote the relative standard errors of π_1 and π_2, respectively, then the standard error of π is

$$\rho = \frac{1}{\pi}\left[t^2 \rho_1^2 \pi_1^2 + (1-t)^2 \rho_2^2 \pi_2^2\right]^{1/2},$$

if one neglects the covariance of π_1 and π_2. If $t = \frac{1}{2}$, this reduces to

$$\rho = \frac{\left[\rho_1^2 \pi_1^2 + \rho_2^2 \pi_2^2\right]^{1/2}}{\pi_1 + \pi_2}.$$

For example the figure 30,174, which is the number of edentulous survivors at age 65 for females in 1971 (table 1), is obtained by multiplying 79,951 by .3774. The prevalence rate of 377.4 per 1,000 used in the latter calculation is the arithmetic mean of the tabular rates 344.5 and 410.3. The respective standard errors of the latter rates, obtained from table 1 and figure I by the method previously described, are 8.3 and 9.8, and the formula for the case of $t = \frac{1}{2}$ gives 3.4 percent for the relative standard error of the interpolated rate. Thus the standard error of the number 30,174 of edentulous survivors is 1.7 percent of 30,174, or 513.

Since the number of dentulous survivors is a constant less the number of edentulous survivors, the absolute standard error is the same, but the relative standard error is different—in this case 513 ÷ 49,777 = 1.0 percent.

A similar calculation at age 75 gives 672 as the standard error of the number 33,596 of edentulous female survivors at that age.

Now, one can observe that for males in 1971 and for each sex in 1957-58 the number of edentulous survivors at age 75 is less than at age 65. Thus the females in 1971 exhibit different behavior in this respect from the other three categories. Is it conceivable that this exceptional behavior could be due to sampling variability? The difference between the numbers at ages 65 and 75 is 3,422 and the standard error of this difference is approximately

$$\left[(513)^2 + (672)^2\right]^{1/2} = 845$$

On the hypothesis that the numbers of edentulous survivors at the two ages are the same in the total population, the standardized deviate is $3{,}422 \div 845 = 4.05$. Thus it is most unlikely that sampling variability accounts for the exceptional behavior.

Standard Errors of Average Remaining Lifetime

The estimation of standard errors of average remaining lifetimes is more complicated, since these quantities are quotients of random variables. First consider the standard error of $\mathring{e}_x^{(d)}$, the average remaining dentulous lifetime of a dentulous person. Since the sum of $\mathring{e}_x^{(d)}$ and $\mathring{e}_x^{(de)}$ is the constant $\mathring{e}_x$ (see appendix I), the standard deviations of $\mathring{e}_x^{(d)}$ and $\mathring{e}_x^{(de)}$ are the same absolute amount.

The procedure for estimating the standard error of $\mathring{e}_x^{(d)}$ is somewhat complicated and is most easily explained by reference to a specific example. Consider, therefore, the estimation of the standard error of $\mathring{e}_{75}^{(d)}$ for females in 1971. If ${}_n\pi_x$ denotes the prevalence rate of edentulousness in the age interval between exact ages x and $x + n$ the formula for $\mathring{e}_{75}^{(d)}$ can be written

$$\mathring{e}_{75}^{(d)} = \frac{{}_5L_{75}(1-{}_5\pi_{75}) + {}_5L_{80}(1-{}_5\pi_{80}) + T_{85}(1-{}_\infty\pi_{85})}{\ell_{75}^{(d)}}$$

$$= \frac{T_{75} - ({}_5\pi_{75}\,{}_5L_{75} + {}_5\pi_{80}\,{}_5L_{80} + {}_\infty\pi_{85}\,T_{85})}{\ell_{75}^{(d)}}.$$

Henceforth the relative standard deviation of ${}_n\pi_x$ is denoted by ${}_n\rho_x$.

The standard error of the numerator of $\mathring{e}_{75}^{(d)}$ is the standard error of the expression within parentheses in the last expression above and, ignoring covariances, can be approximated by

$$\sigma_{Num} \doteq [{}_5\rho_{75}^2\,{}_5\pi_{75}^2\,{}_5L_{75}^2 + {}_5\rho_{80}^2\,{}_5\pi_{80}^2\,{}_5L_{80}^2 + {}_\infty\rho_{85}^2\,{}_\infty\pi_{85}^2\,T_{85}^2]^{1/2} = 12512.$$

The standard error of the denominator is the same as that of $\ell_{75}^{(e)}$, which was previously shown to be 672.

If one denotes the corresponding relative standard errors by ρ_{Num} and ρ_{Den}, the relative standard error of a ratio of two random variables is approximated by[9]

$$\rho_{ratio}^2 \doteq \rho_{Num}^2 + \rho_{Den}^2 - 2\gamma_{Num,\,Den},$$

where $\gamma_{Num,\,Den}$ denotes the relative covariance of the numerator and denominator. Inasmuch as a positive multiple of the denominator is essentially one of the components of the numerator, the covariance is almost certainly positive, and therefore

$$\rho_{ratio} \leq (\rho_{Num}^2 + \rho_{Den}^2)^{1/2}.$$

In the present case,

$$\rho_{Num} = 12512/233133 = .05367,$$

$$\rho_{Den} = 672/27565 = .02438,$$

and an upper bound to the relative standard error of $\mathring{e}_{75}^{(d)}$ is

$$[(.05367)^2 + (.02438)^2]^{1/2} = .0589,$$

or 5.9 percent. The true relative standard error of $\mathring{e}_{75}^{(d)}$ is probably substantially less.

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APPENDIX III

IMPLIED INCIDENCE RATES

In the methodology used in the construction of the detailed tables and described in appendix I, prevalence rates of edentulousness were used in a makeshift fashion because incidence rates were not available. This was made possible by some rather sweeping assumptions described in the main text and in appendix I. As incidence rates would seem to be a necessary ingredient for obtaining the kind of results presented in tables 1-4, some incidence rates must be implicit in the assumptions made. Though no actual use was made of them, it may be of some theoretical interest to discover what rates these are.

The incidence rate for a condition is usually defined[10] as the number of new cases of the condition occurring during a specified period of observation divided by the average population during the period of observation. Those persons who already have the condition under study are not excluded from the population in the denominator. Consider the ${}_nL_x$ persons who are in the age interval x to $x + n$ at a given moment. The number of new cases of edentulousness occurring in this group during the succeeding n years is, on the assumptions made in this report,

$$ {}_nL^{(e)}_{x+n} - \frac{{}_nL_{x+n}}{{}_nL_x} \; {}_nL^{(e)}_x . $$

The first term is the number edentulous n years later at ages n years older. The subtractive term is the number of survivors n years later of those in the original group who were already edentulous at the initial moment.

Noting that

$$ {}_nL^{(e)}_x = {}_n\pi_x \; {}_nL_x $$

and dividing the number of new cases by ${}_nL_x$, one obtains for the incidence rate

$$ ({}_n\pi_{x+n} - {}_n\pi_x)\frac{{}_nL_{x+n}}{{}_nL_x} $$

One may observe that this expression is the product of two factors: an n-year survival rate for the stationary population, and a difference between successive prevalence rates. This is reminiscent of the multiplicative theory of multiple decrement tables and the associated single decrement tables.[11]

It is interesting to note that Klein[3] obtained incidence rates by differencing prevalence rates without, however, offering any theoretical justification for this procedure.

If prevalence rates for some morbid condition (from which recovery is impossible) do not increase monotonically with age, this would imply negative incidence rates, and the model would be untenable.

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