Prevalence and Distribution of Dental Restorative Materials in US Air Force Veterans

Tullio F. Albertini, DDS, MPH; Albert Kingman, PhD; L. Jackson Brown, DDS, PhD

Abstract

Objectives: *Millions of restorative procedures are performed annually in the United States, yet very little is known about their distribution in the general population. With increasing concern about potential adverse health effects of some restorative materials, a better understanding of the extent of exposure to these materials in the population is important. The purpose of this study is to report the prevalence, patterns, and distribution of dental restorative materials in a population of male veterans.* ***Methods:*** *This collaborative study with the US Air Force examined 1,166 male veterans to assess exposure to dental amalgam and other restorative materials. An inventory of dental materials in the study population was obtained through oral examinations. Dental materials were classified into five categories: (1) amalgam; (2) resin; (3) porcelain, cement, or temporary, including ionomer (PCT); (4) cast gold alloys/direct filling gold; and (5) other metals (OM). The mean age of the study participants was 52.9 years. Over 94 percent of the study participants were dentate.* ***Results:*** *The study participants averaged 45.8 restored/replaced surfaces. Restored/replaced surfaces increased with age while the number of teeth decreased with age. The most frequently used restorative material was amalgam, averaging 19.89 surfaces per subject, followed by PCT (9.38), resins (8.99), OM (5.52), and gold (4.91). The distributions of restorative materials varied by age, arch type, and location in the mouth.* ***Conclusions:*** *The study population experienced substantial exposure to dental materials. [J Public Health Dent 1997;57(1):5-10]*

Key Words: dental restorations, dental materials, dental epidemiology, health services, oral health, adults, United States.

Over 200 million restorative procedures were performed in the United States in 1989, of which almost half were amalgam procedures (1). Other materials frequently used in dental restorative procedures include, but are not limited to, plastic and composite restorative materials, glass ionomer cements, casting alloys, and porcelains (2-4).

While the dental literature contains numerous studies describing the composition, physical properties, functional characteristics, and longevity of dental restorative materials, detailed information about the prevalence and distribution of these materials in the general adult population could not be found (5-7). Only one study of Danish 20-year-old military conscripts describing caries treatment patterns was found that recorded the type of restorative material used in restorations (8). That study reported an increase in the proportion of occlusal fillings composed of tooth-colored resin materials from 0.5 percent in 1986 to 6.0 percent in 1991. However, a description of the patterns of use of other dental restorative materials was not presented.

Changing dental caries prevalence and improvements in dental materials have stimulated substantial scientific interest in new treatment paradigms (9-12). However, information describing changes in dental materials preferences by dentists over time is sparse. In one study (13), a survey questionnaire was sent to 500 practicing dentists in the state of Virginia to ascertain the use of composite resins versus the use of dental amalgams in class II preparations. Less than 20 percent of the respondents indicated using composite resins in all areas of the mouth and only 5.2 percent of the respondents stated that they routinely replaced existing class II amalgams with composite resins.

While epidemiologic indices (DMFT/DMFS) are useful for describing the prevalence and sequelae of dental caries, these indices are inadequate for describing the extent and distribution of specific dental restorative materials, since they do not record the type of materials (14). Additionally, because dental caries takes precedence over restorations in these indices, the number of restored surfaces is subject to underestimation.

The National Institute of Dental Research Amalgam Study was started in the fall of 1992 as a collaboration with the US Air Force. An oral health component was incorporated into the Air Force Health Study (AFHS), an ongoing 20-year prospective health study of Air Force veterans who served during the Vietnam War (15). The objectives of this study were to investigate the health effects of exposure to dental amalgams and to assess the level of exposure to other commonly used dental restorative materials within the study population. The purpose of this paper is to report on the prevalence, patterns, and distribution of dental restorative materials found in this male veteran population.

Methods

Two trained dentists performed oral health examinations as a separate component of the overall 1992–93 health assessment protocol. The visual-tactile assessment employed the use of front surface mirrors, a number

Send correspondence and reprint requests to Dr. Albertini, Division of Intramural Research, National Institute of Dental Research, National Institutes of Health, Natcher Building, Room 4AS-13E, 45 Center Drive (MSC 6401), Bethesda, MD 20892. Internet: albertinit@de45.nidr.nih.gov. Dr. Kingman is also affiliated with the NIDR's Division of Intramural Research. Dr. Brown is with the American Dental Association. Manuscript received: 2/23/96; returned to authors for revision: 4/12/96; accepted for publication: 7/17/96.

23 explorer, and high-intensity lighting. Coronal caries was assessed using the standard NIDR criteria used in epidemiologic surveys and clinical trials (16). In this study, all 32 tooth positions were scored, since the focus of the study was on exposure to dental restorative materials.

As part of a comprehensive oral health examination, a complete inventory of dental restorative materials present on all coronal surfaces of existing and replaced teeth was performed. Replaced teeth included pontics on fixed bridges, replacements on partial removable dentures, and full dentures. Crowns were considered restored surfaces of teeth present. In instances where surfaces contained more than one material, each material was identified and recorded separately. Dental materials were classified into five general categories: amalgam (A); composite or acrylic resin (R); porcelain, cement, or temporary (includes glass ionomer restorations and the porcelain surfaces of PFM crowns) (PCT); cast gold alloy/direct filling gold (G); and other metals (OM). Henceforth, for brevity, the category of cast gold alloy/direct filling gold will be referenced as "gold."

A detailed written manual was prepared providing documentation of all criteria used in the oral health examination. The reference manual served as a useful guide throughout the course of the study. Extensive training sessions were conducted for the participating dentists prior to the commencement of the study to ensure proficiency in the use of these criteria. Evaluations of examiner proficiency and reliability were performed prior to the commencement of the study and were repeated during the study period, as well. Intraclass correlations were used to evaluate subject-based scores, and kappa statistics were used for tooth- and surface-based scores. At the tooth and surface level, the kappa statistics ranged from 0.77 to 1.00 for pairs of examiners and each restorative material type. Data were recorded on optical scan forms for speedy transfer to computer files. Field operations and data collection were subjected to rigorous quality control. Before analysis, data were verified, edited, and all changes were documented.

A total of 1,210 Air Force Health Study (AFHS) male participants were eligible to participate in the oral health component. Informed consent was obtained from 1,166 (96%) of these participants. A few potential participants were excluded from the study due to preexisting medical conditions.

Various graphical and descriptive analyses were performed, including distributional plots, various graphical techniques, and summary statistics for specific variables, including their means, variances, and standard errors. Specific subgroups were compared using standard statistical test procedures, including the student-T, chi-square, analysis of variance, Pearson's correlation, multiple regression, and Hotelling's T^2.

Results

The mean age of these study participants was 52.9 years and ranged from 40 to 78 years. Sixty-one participants (5.2%) were black, the remaining 1,105 were nonblack. Other racial/ethnic categories were not identified. The age and dentate status of participants are given in Table 1. Ninety-five percent of the participants were between the ages of 40 and 65. Overall, 5.2 percent (61 participants) were edentulous. The average ages of the dentate and edentulous participants were 52.7 years and 56.8 years, respectively. The proportion of edentulous persons increased with age (chi-square=14.8, P=.001).

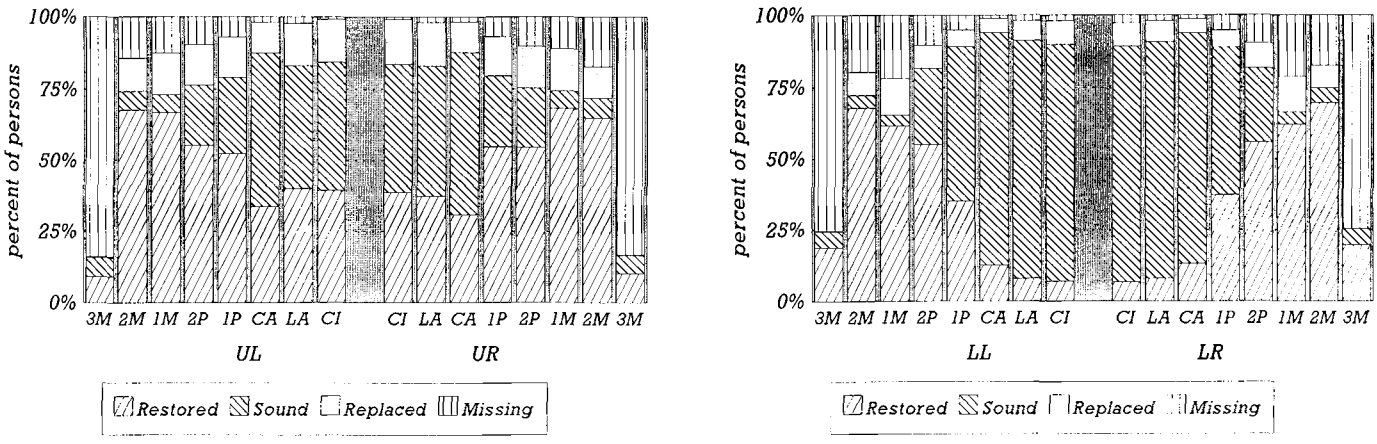
TABLE 1
Number and Percent of Study Participants by Age Group and Dentate Status

	Dentate		Edentulous		Total	
Age Group (Years)	Number	Percent	Number	Percent	Number	Percent
40–44	105	9.5	1	0.9	106	9.1
45–49	392	35.5	13	3.2	405	34.7
50–54	182	16.5	12	6.1	194	16.6
55–59	193	17.5	13	6.3	206	17.7
60–64	175	15.8	15	7.8	190	16.3
65–79	58	5.2	7	10.7	65	5.6
All	1,105	100.0	61	5.2	1,166	100.0

TABLE 2
Mean Number of Restored or Replaced Teeth and Surfaces in Dentate Subjects by Age Group

Age Group (Years)	Number of Persons	Mean Number Teeth (SE)	Mean Number Surfaces (SE)	Mean Number Surfaces Restored (SE)	Mean Number Surfaces Replaced (SE)	Total Restored and Replaced Surfaces (SE)
40–44	105	25.66 (0.45)	116.80 (2.14)	30.91 (2.01)	4.34 (1.31)	35.25 (2.36)
45–49	392	26.12 (0.21)	119.12 (1.00)	34.66 (0.98)	4.53 (0.68)	39.18 (1.10)
50–54	182	25.80 (0.38)	117.67 (1.79)	40.32 (1.47)	6.36 (1.39)	46.68 (1.74)
55–59	193	23.92 (0.46)	108.77 (2.19)	39.83 (1.65)	11.86 (1.75)	51.69 (1.89)
60–64	175	23.25 (0.46)	105.47 (2.16)	42.21 (1.81)	13.05 (1.79)	55.25 (2.13)
65–79	58	21.71 (0.83)	98.24 (3.85)	41.00 (2.68)	17.72 (3.49)	58.72 (3.46)
All	1,105	24.95 (0.16)	113.60 (0.77)	37.67 (0.64)	8.13 (0.59)	45.80 (0.76)

FIGURE 1
Tooth-specific Distributions of Restored, Missing, and Replaced Teeth for All Subjects (Source: NIDR Amalgam Study)



The dentate population (n=1,105) averaged 25 teeth per person. Distributions for the mean numbers of teeth and surfaces per participant are given in Table 2. A regression analysis demonstrated a negative gradient in the mean number of teeth with age (β=–0.65, P=.023). These participants averaged 113.6 natural tooth surfaces per person, of which slightly more than one-third (37.67 surfaces) were restored. The dentate participants averaged 8.13 replaced tooth surfaces. Regression analysis showed the mean number of restored or replaced surfaces increased with age (β=1.2, P=.003) from 35.25 surfaces in individuals 40–44-year-old age group to 58.72 surfaces for the 65–79-year-old age group.

Tooth-specific distributions of restored and replaced teeth are presented in Figure 1. Approximately 75 percent of these study participants retained all of their first and second molars. Molar teeth had the highest number of restorations in both arches. While slightly more second molars than first molars were restored in the mandibular arch, this difference was not observed in the maxillary arch. The largest contrast by arch was observed in anterior teeth. In the maxillary arch 30 percent to 45 percent of the participants had restorations on incisors and canines, whereas only 10 percent to 14 percent had restorations for similar mandibular anterior teeth. In twenty-five percent of these participants both mandibular third molars were visibly present, while slightly fewer participants (18%) presented with both maxillary third molars. Bilateral quadrant profiles of restored and replaced teeth were very similar within each arch.

TABLE 3
Mean Number and Percent of Surfaces Restored or Replaced in Dentate Subjects by Material Type

	Surfaces					
	Restored		Missing/Replaced		All	
Material Type	# (SE)	Percent	# (SE)	Percent	# (SE)	Percent
Amalgam	19.89 (0.37)	52.8	0.00 (0.00)	0.0	19.89 (0.37)	43.4
Resin	3.58 (0.14)	9.5	5.41 (0.54)	66.5	8.99 (0.54)	19.6
PCT	7.93 (0.38)	21.1	1.45 (0.20)	17.8	9.38 (0.44)	20.5
Gold	4.55 (0.25)	12.1	0.36 (0.05)	4.4	4.91 (0.26)	10.7
Other metals	4.28 (0.21)	11.4	1.24 (0.09)	15.3	5.52 (0.26)	12.1
All types	37.67 (0.64)	—	8.13 (0.59)	—	45.80 (0.76)	—

The mean number and percent of restored and replaced surfaces for each restorative material group are presented in Table 3. The most prevalent restorative material for dentate persons was amalgam, averaging 19.89 surfaces per participant. Substantially fewer tooth surfaces, 8.99 and 9.38, contained resin and PCT, respectively; while other metals and gold were found on 5.52 and 4.91 surfaces, respectively (F=12.3, P=.001). Tukey's multiple comparisons procedure (using α=0.05) showed that these restorative materials fell into three statistically distinct frequency groups: surfaces restored with amalgam (19.89) were the most numerous, surfaces restored with PCT (9.4) and resin (9.0) were the next most prevalent group, and surfaces restored with other metals (5.5) and gold (4.9) were the least prevalent. The number of observed surfaces restored with amalgam ranged from 0 to 66. The maximum number of restored and replaced surfaces containing resin was 120; PCT, 126; gold, 58; and other metals, 65.

The mean number of natural tooth surfaces per person restored by the different restorative materials is presented in Table 4. Each restorative ma-

TABLE 4
Mean Number (SE) of Natural Surfaces Restored in Dentate Subjects by Age Group and Material Type

Age Group (Years)	Material Type					
	Amalgam	Resin	PCT	Gold	Other Metals	All Types*
40–44	19.41	2.94	5.70	1.68	3.05	30.91
	(1.11)	(0.42)	(0.91)	(0.39)	(0.63)	(2.01)
45–49	20.52	3.37	5.83	3.62	3.16	34.66
	(0.57)	(0.23)	(0.46)	(0.37)	(0.27)	(0.98)
50–54	22.26	3.46	7.55	5.62	3.74	40.32
	(0.91)	(0.31)	(0.89)	(0.68)	(0.49)	(1.47)
55–59	19.41	4.07	9.59	4.68	5.00	39.83
	(1.01)	(0.36)	(0.99)	(0.57)	(0.52)	(1.65)
60–64	18.51	3.89	11.47	5.89	6.50	42.21
	(0.93)	(0.38)	(1.28)	(0.68)	(0.64)	(1.81)
65–79	14.74	4.02	11.12	8.33	6.72	41.00
	(1.64)	(0.80)	(2.01)	(1.34)	(1.06)	(2.69)
All	19.89	3.58	7.93	4.55	4.28	37.67
	(0.37)	(0.14)	(0.38)	(0.25)	(0.21)	(0.64)

*Surfaces restored with multiple restorative materials are counted only once.

TABLE 5
Mean Number (SE) of Anterior Surfaces Restored in Dentate Subjects by Age Group and Material Type

Age Group (Years)	Material Type					
	Amalgam	Resin	PCT	Gold	Other Metals	All Types*
40–44	0.52	2.56	2.32	0.03	1.04	5.64
	(0.10)	(0.37)	(0.54)	(0.03)	(0.31)	(0.75)
45–49	0.70	2.83	1.79	0.17	0.92	5.67
	(0.07)	(0.19)	(0.21)	(0.05)	(0.12)	(0.33)
50–54	0.90	2.76	2.01	0.12	1.01	5.93
	(0.10)	(0.28)	(0.36)	(0.04)	(0.21)	(0.50)
55–59	0.98	3.40	2.11	0.52	0.98	7.23
	(0.11)	(0.33)	(0.33)	(0.15)	(0.16)	(0.53)
60–64	1.16	3.19	2.97	0.11	1.53	7.68
	(0.13)	(0.34)	(0.53)	(0.05)	(0.23)	(0.64)
65–79	0.74	2.93	3.03	0.62	1.38	7.50
	(0.17)	(0.63)	(1.00)	(0.22)	(0.41)	(1.13)
All	0.84	2.96	2.19	0.22	1.08	6.40
	(0.04)	(0.12)	(0.16)	(0.04)	(0.08)	(0.22)

*Surfaces restored with multiple restorative materials are counted only once.

terial group exhibited a different variation with age. Regression analysis showed a quadratic relationship in age for the number of surfaces restored with amalgam (β_1=2.20, SE=0.72, P=.0023; β_q=–0.02, SE=.007, P=.0011). The mean number of amalgam surfaces increased among younger participants, peaked for those in their early 50s, and then diminished with age. The mean number of amalgam surfaces ranged from a high of 22.26 surfaces for the 50–54-year-old age group to 14.74 for the 65 years and older age group. A very slight increase in the mean number of resin surfaces by age (β=0.05, P=.015) also was observed. The mean number of surfaces for all other restorative material groups also increased with age (PCT: β=0.29, P=.0001; gold: β=0.19, P=.0001; other metals: β=0.18, P=.0001).

The distribution of restorative materials differs by location in the mouth. Tables 5 and 6 show the relative distributions for anterior and posterior teeth, respectively. Although all materials were present in both anterior and posterior teeth, posterior teeth contained more surfaces restored with amalgam, PCT, gold, and other metal, while anterior teeth contained more surfaces restored with resin.

Differences were evident in the distributions of dental restorations and restorative material groups between arches. Overall, in the dentate population, the maxillary arch contained an average of almost five additional restored surfaces than did the mandibular arch. As Table 7 shows, the mean number of restored surfaces in the maxillary arch for each of the material types was as follows: amalgams, 10.62; resins, 2.82; PCT, 5.03; gold, 1.76; and other metals, 2.60. In the mandibular arch the mean number of restored surfaces for the different restorative material types were: amalgam, 9.27; resin, 0.76; PCT, 2.90; gold, 2.79; and other metals, 1.69. Hotelling's T^2 test statistic was used to test and reject that differences (1.35, 2.06, 2.13, –1.03, 0.91) between the maxillary and mandibular means for each restorative material group was jointly 0 (T^2=9.34, P=.003).

Discussion

While numerous studies have been published describing physical characteristics, longevity, and quality of restorations and dental restorative materials, no study describing an inventory of restorative materials in a free-standing, nonclinic population could be found. The NIDR amalgam study provides the first report of the distribution of dental restorative materials in a large cohort of adult males.

Due to the specific characteristics of this study population, the pattern of materials found in this population may be different from that found in the adult US population. This study group served in the US Air Force during the Vietnam War and could have received somewhat different dental care than that received by US adults in general. Also, the study did not include females. However, this cohort does represent various socioeconomic strata,

TABLE 6
Mean Number (SE) of Posterior Surfaces Restored in Dentate Subjects by Age Group and Material Type

Age Group (Years)	Material Type					
	Amalgam	Resin	PCT	Gold	Other Metals	All Types*
40–44	18.89 (1.08)	0.38 (0.12)	3.37 (0.60)	1.65 (0.39)	2.01 (0.45)	25.28 (1.52)
45–49	19.81 (0.55)	0.54 (0.09)	4.04 (0.37)	3.45 (0.36)	2.24 (0.21)	28.99 (0.79)
50–54	21.36 (0.88)	0.70 (0.13)	5.55 (0.79)	5.50 (0.68)	2.73 (0.38)	34.39 (1.26)
55–59	18.42 (0.98)	0.67 (0.11)	7.48 (0.83)	4.16 (0.54)	4.02 (0.45)	32.61 (1.34)
60–64	17.35 (0.89)	0.70 (0.14)	8.50 (0.90)	5.78 (0.69)	4.97 (0.52)	34.53 (1.42)
65–79	14.00 (1.57)	1.09 (0.53)	8.09 (1.34)	7.71 (1.28)	5.34 (0.95)	33.50 (2.32)
All	19.04 (0.36)	0.63 (0.06)	5.74 (0.30)	4.33 (0.24)	3.21 (0.17)	31.27 (0.52)

*Surfaces restored with multiple restorative materials are counted only once.

TABLE 7
Mean Number of Surfaces Restored by Type of Material and Arch

Material Type	Mean Number Surfaces	Maxillary Arch		Mandibular Arch	
		Number (SE)	Percent	Number (SE)	Percent
Amalgam	19.89	10.62 (0.23)	50.3	9.27 (0.20)	56.0
Resin	3.58	2.82 (0.12)	13.3	0.76 (0.06)	4.6
PCT	7.93	5.03 (0.24)	23.8	2.90 (0.18)	17.6
Gold	4.55	1.76 (0.12)	8.3	2.79 (0.16)	16.9
Other metals	4.28	2.60 (0.14)	12.3	1.69 (0.11)	10.2
All types	37.67	21.13		16.54	

with both enlisted personnel and officers included.

All study participants, upon entering the armed forces, received routine dental examinations and were eligible for free dental care. Furthermore, substantial efforts are usually made to bring individuals billeted for duty overseas, especially in theaters of war, to an optimal functional state of oral health. The extent to which these special efforts and access to free dental care affected the type and quantity of dental care received in this study population is unknown. However, a recent study comparing the dental utilization of US Army soldiers to an employed civilian population provides an indication of the differences in utilization between a military and civilian population (17). The study surveying 5,474 enlisted and 4,036 officer active duty US Army personnel had an overall response rate of 62 percent. The investigator found that overall more than 80 percent of US Army personnel had been seen by a dentist within the past year, and when controlling for age, sex, and race, active duty Army personnel had dental utilization rates that greatly exceeded their employed civilian counterparts.

In an effort to assess the extent to which the US Air Force study population differed from their male counterparts in the general population, comparisons were made between the study subjects and employed males in the US based upon the 1985–86 NIDR National Survey of Oral Health in US Employed Adults and Seniors (18). Age-adjusted comparisons revealed that the Air Force study population had a higher overall number of decayed and filled surfaces (DFS), more restored teeth, and fewer missing teeth, on average, than their counterparts in the adult male, employed, noninstitutionalized population.

Thus, it appears that the study population probably received more restorative dental care, had more exposure to dental materials, and may have experienced a higher level of exposure to amalgam than their civilian counterparts. The level of untreated caries, as reflected by the ratio of decayed surfaces (DS) to decayed and filled surfaces (DFS), for the general US population of adult males was about 5 percent, as contrasted with 2 percent for the study group. The degree to which the choice of materials used in restoring tooth surfaces differs between military dental care and the private practice sector serving the general adult population remains unknown because the 1985–86 NIDR survey did not record types of restorative materials.

Since radiographs are rarely used in large-scale epidemiologic studies and were not used in this study, it is possible that the number of proximal surfaces containing restorative materials was underestimated. However, any underestimation is likely to be very small because most restorative materials are detected readily. Additionally, any underestimation should not be substantially different from that of the 1985–86 NIDR survey.

Another recent study explored the attitudes and practices of dentists toward the use of resin-based composite materials in class II preparations as compared to amalgam for the same types of restorations (13). A questionnaire was mailed to 500 dentists in Virginia with 313 (63%) responding. The study concluded that while 19 percent of respondents are using composite resins to restore lesions in all areas of the mouth, amalgam was still the dentists' material of choice by almost 5 to 1 for posterior class II restorations and only about 5 percent of respondents were routinely replacing existing class II amalgams with composites. The NIDR amalgam study also found amalgam to be the most

prevalent restorative material in use by a 2:1 margin over resins and PCTs.

The extent of restorative materials present varied with age. Cast metals and PCTs all increased with age, while the observed number of surfaces restored with amalgam decreased with age. Although the mean number of surfaces decreased with age as teeth were lost, the proportion of tooth surfaces that were restored increased with age. It is well established that restored teeth are at increased risk for rerestoration (19-22). Furthermore, recent evidence suggests that retreatment of previously restored teeth leads to an increase in restoration size (23).

Thus, it is possible that surfaces restored with crowns increase with age as a consequence of rerestoration of previously restored teeth. Since this is a cross-sectional study, it is not possible to test this hypothesis directly. However, the average number of crowns found in this study population did, in fact, increase with age, ranging from a low of 1.4 crowns per person in the 40–44-year-old age group to a high of 3.8 crowns per person in the 65–79-year-old age group. This indirect evidence tends to support the hypothesis of a substitution effect of crowns for intracoronal restorations. If the hypothesis is correct, the actual number of surfaces restored with amalgam, composite, or glass ionomer could be underestimated, since teeth containing these materials that subsequently are crowned have not necessarily had their intracoronal restorations removed. The extent of such "hidden" restorations is unknown and the degree to which they constitute exposure to these materials also is not known.

Acknowledgments

This study was funded by the National Institute of Dental Research and implemented in collaboration with the Human Systems Center of the Department of the United States Air Force under Interagency agreement 1YO1-DE-20037. Data collection was performed by Science Applications International Corporation under contract NO1DE-22595. Analysis of the data was performed by the staff of the Division of Intramural Research, National Institute of Dental Research, National Institutes of Health. The authors would also like to express their sincere appreciation to Scripps Research Clinic; Mayo Clinic Laboratory; Loma Linda Dental School; Department of Restorative Dentistry, University of Iowa Dental School; Department of Chemistry, American Dental Association; Department of Environmental Health, University of Rochester; and Oral Health America, America's Fund for Dental Health, for their invaluable contributions to this study.

References

1. Nash KD, Bentley JE. Is restorative dentistry on its way out? J Am Dent Assoc 1991;122:79-80.
2. American Dental Association. Guide to dental materials and devices. 7th ed. Chicago, IL: American Dental Association, 1974-75.
3. Van Noort R, Brown D, Clarke R, et al. Dental materials: 1992 literature review. J Dent 1994;22:5-28.
4. Christensen GJ. Glass ionomer-resin: a maturing concept. J Am Dent Assoc 1993; 124:248-9.
5. Barnes DM, Blank LW, Gingell JC, Gilner PP. A clinical evaluation of resin-modified glass ionomer restorative material. J Am Dent Assoc 1995;126:1245-53.
6. Wilson NH. The limitations of resin-bonded restorations. Ann Acad Med Singapore 1995;24:52-7.
7. Meeuwissen R, van Elteren PH, Eschen S, Mulder J. Durability of amalgam restorations in premolars and molars in Dutch servicemen. Community Dent Health 1985;2:293-302.
8. Ekstrand KR, Carvalho JC, Thylstrup A. Restorative caries treatment patterns in Danish 20-year-old-males in 1986 and 1991. Community Dent Oral Epidemiol 1994;22:75-9.
9. Qvist V, Strom C. 11-year assessment of class-III resin restorations completed with two restorative procedures. Acta Odontol Scand 1993;51:253-62.
10. Croll TP. Lateral-access class II restoration using resin-modified glass-ionomer or silver-cermet cement. Quintessence Int 1995;26:121-6.
11. Croll TP, Cavanaugh RR. Vitremer cement for class I restoration of permanent teeth. Pract Periodont Aesthetic Dent 1994;6:25-32.
12. Franchi M, Trisi P, Montanari G, Piattelli A. Composite resin-amalgam compound restorations. Quintessence Int 1994;25: 577-82.
13. Shepard FE, Jones CK, Janus CE. A survey and analysis of dental materials and placement techniques utilized for direct restorations by Virginia dentists. VA Dent J 1991;68:12-17.
14. Klein H, Palmer CE, Knutson JW. Studies on dental caries. Public Health Rep 1938; 53:751-65.
15. Air Force health study: an epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides. Brooks Air Force Base, TX: Epidemiology Research Division, Armstrong Laboratory, Human Systems Division (AFSC), 1991.
16. Carlos JP, Brunelle JA. Oral health surveys of the National Institute of Dental Research: diagnostic criteria and procedures. NIH pub no 91-2870. Bethesda, MD: National Institute of Dental Research, 1991.
17. Chisick MC. Comparing dental utilization of US Army soldiers with their employed civilian cohorts. Community Dent Oral Epidemiol 1995;23:222-5.
18. Miller AJ, Brunelle JA, Carlos JP, Brown LJ, Löe H. Oral health of United States adults: the National Survey of Oral Health in Employed Adults and Seniors: 1985-86. NIH pub no 87-2868. Bethesda, MD: National Institute of Dental Research, 1987.
19. Mjör IA. Amalgam and composite restorations: longevity and reasons for replacement. In: Anusavice KJ, ed. Quality evaluation of dental restorations: criteria for placement and replacement. Chicago, IL: Quintessence 1989:61-72.
20. Boyd MA, Richardson AS. Frequency of amalgam replacement in general dental practice. J Can Dent Assoc 1985;51:763-6.
21. Mjör IA. Placement and replacement of restorations. Oper Dent 1981;6:49-54.
22. Qvist V, Johannessen L, Lambjerg-Hansen H, Thylstrup A. Replacement of class III and V composite resin and silicate cement restorations. J Dent Res 1984;63: 576.
23. Brantley CF, Bader JD, Shugars DA, Nesbit SP. Does the cycle of rerestoration lead to larger restorations? J Am Dent Assoc 1995;126:1407-13.