Concentrations of waste inhalation anesthetic gases in the dental surgery are several times those found in hospital operating rooms. This study establishes a relationship between exposure to waste gases and the incidence of health problems including spontaneous abortion in spouses, congenital abnormalities in offspring, and cancer and liver disease.

A survey of anesthetic health hazards among dentists

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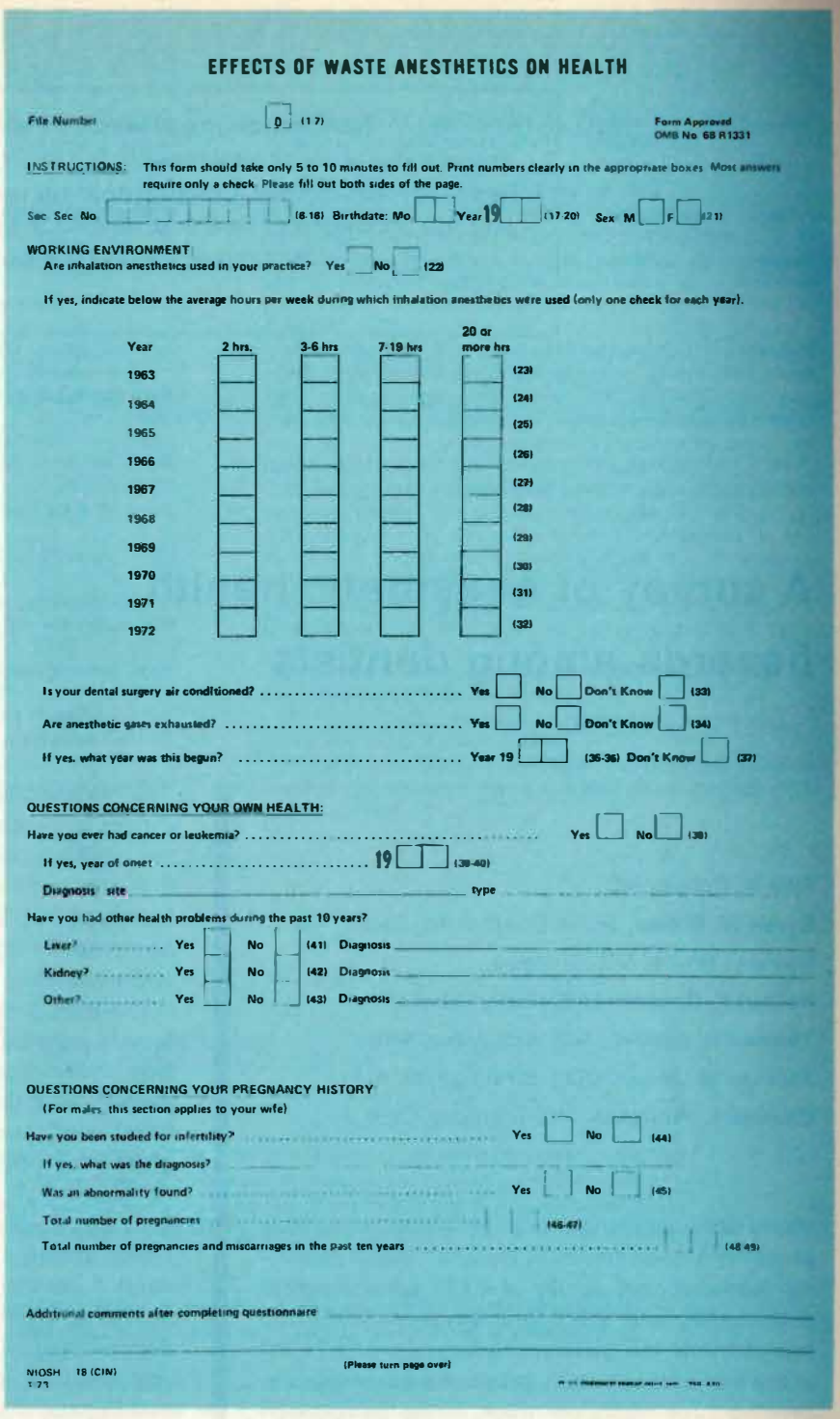
Measurable concentrations of waste anesthetic gases have been found in hospital dental operating rooms. A mail survey of 4,797 general dental practitioners and 2,642 oral surgeons indicated that 20.2% of the general practitioners and 74.8% of the oral surgeons had anesthetic exposures exceeding three hours per week. In the comparison of the health of individuals exposed or unexposed to inhalation anesthetics, there was a significant increase (78%) of spontaneous abortion in the spouses of exposed dentists and a significant increase (156%) in liver disease for exposed dentists. The implication of these findings and possible solutions are discussed.

The widespread application of inhalation anesthetics in dentistry raises the question of potential health hazards to personnel exposed during this anesthetic administration. In 1967, Vaisman[1] surveyed 303 Russian anesthetists and reported an unusually high incidence of headache, fatigue, and irritability. Of great interest, he also noted that a high percentage of the pregnancies among female anesthetists ended in spontaneous abortion. Subsequent small-scale studies in Denmark,[2] the United States,[3] and the United Kingdom[4] confirmed these findings and further suggested the possibility of an increased incidence of congenital abnormalities for exposed pregnant physicians[4] and of cancer among exposed nurse anesthetists.[5] Recently, a large national study,[6] investigating the health conditions of operating personnel in the United States, has documented significant increases in spontaneous abortion, congenital abnormalities, cancer, and hepatic disease among women who work in the operating room and who are exposed to waste anesthetic gases. Although a cause-effect relationship between the incidence of these diseases and exposure to the waste anesthetic gases remains to be established, such an explanation appears reasonable, and results of several animal studies provide strong supporting evidence for this hypothesis.

Report of an American Society of Anesthesiologists Ad Hoc Committee on the Effect of Trace Anesthetics on the Health of Operating Room Personnel



EFFECTS OF WASTE ANESTHETICS ON HEALTH

File Number 0 (1-7)

Form Approved
OMB No 68-R1331

INSTRUCTIONS: This form should take only 5 to 10 minutes to fill out. Print numbers clearly in the appropriate boxes. Most answers require only a check. Please fill out both sides of the page.

Soc Sec No (8-16) Birthdate: Mo Year 19 (17-20) Sex M F (21)

WORKING ENVIRONMENT

Are inhalation anesthetics used in your practice? Yes No (22)

If yes, indicate below the average hours per week during which inhalation anesthetics were used (only one check for each year).

Year	2 hrs.	3-6 hrs	7-19 hrs	20 or more hrs	
1963					(23)
1964					(24)
1965					(25)
1966					(26)
1967					(27)
1968					(28)
1969					(29)
1970					(30)
1971					(31)
1972					(32)

Is your dental surgery air conditioned? ..... Yes No Don't Know (33)

Are anesthetic gases exhausted? ..... Yes No Don't Know (34)

If yes, what year was this begun? ..... Year 19 (35-36) Don't Know (37)

QUESTIONS CONCERNING YOUR OWN HEALTH:

Have you ever had cancer or leukemia? ..... Yes No (38)

If yes, year of onset 19 (39-40)

Diagnosis site _____ type _____

Have you had other health problems during the past 10 years?

Liver? ..... Yes No (41) Diagnosis _____

Kidney? ..... Yes No (42) Diagnosis _____

Other? ..... Yes No (43) Diagnosis _____

QUESTIONS CONCERNING YOUR PREGNANCY HISTORY

(For males, this section applies to your wife)

Have you been studied for infertility? ..... Yes No (44)

If yes, what was the diagnosis? _____

Was an abnormality found? ..... Yes No (45)

Total number of pregnancies ..... (46-47)

Total number of pregnancies and miscarriages in the past ten years ..... (48-49)

Additional comments after completing questionnaire _____

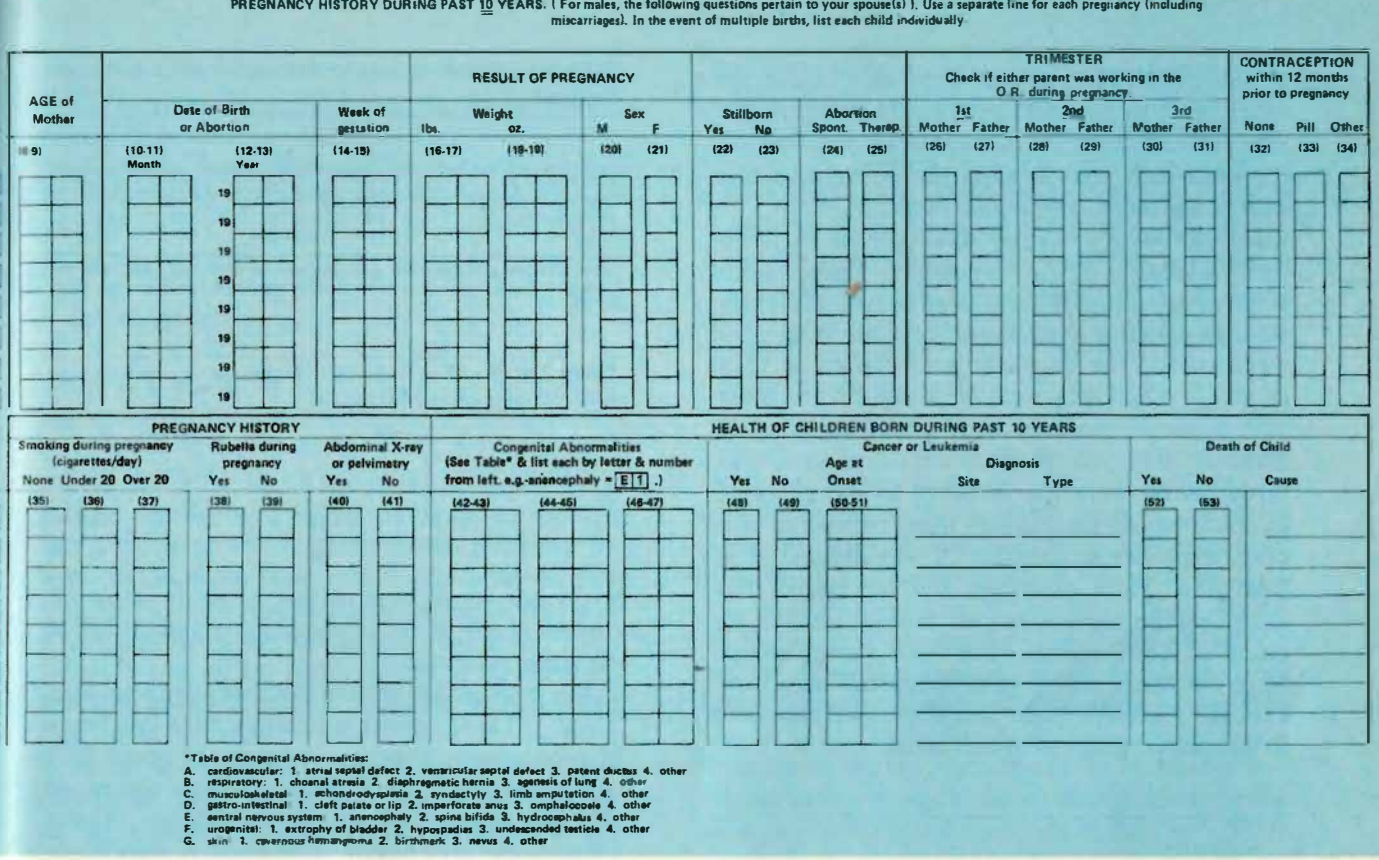
(Please turn page over)

NIOSH 18 (CIN)
1-73

Fig 1 ■ Front of questionnaire mailed to ASOS and ADA members.

Measurable concentrations of waste anesthetic gases are found in both general operating rooms[7-10] and in hospital dental operating rooms according to two reports[11,12] and a communication from one of us (C.E.W.). These studies of ambient gas concentrations during dental surgery indicate that the concentration of halothane in unvented (unscavenged) rooms may exceed 73 ppm and that the unscavenged concentration of nitrous oxide ranges from 500 to 6,000 ppm (0.05% to 0.6%). The number of individuals occupationally exposed to these trace concentrations of anesthetics is large and includes significant segments of the dental profession, as well as associated nurse anesthetists and dental assistants. The number of exposed personnel in the United States (dentists and assistants) may conservatively be estimated to exceed 90,000 individuals.

This paper reports the results of a survey of certain health conditions among members of the dental profession. All male members (2,798) of the American Society of Oral Surgeons were included in a retrospective survey, in addition to a


PREGNANCY HISTORY DURING PAST 10 YEARS. (For males, the following questions pertain to your spouse(s)). Use a separate line for each pregnancy (including miscarriages). In the event of multiple births, list each child individually

AGE of Mother	Date of Birth or Abortion		Week of gestation	RESULT OF PREGNANCY: Weight lbs.	Weight oz.	Sex M	Sex F	Stillborn Yes	Stillborn No	Abortion Spont.	Abortion Therap.	TRIMESTER Check if either parent was working in the O.R. during pregnancy: 1st Mother	1st Father	2nd Mother	2nd Father	3rd Mother	3rd Father	CONTRACEPTION within 12 months prior to pregnancy: None	Pill	Other
(8-9)	(10-11) Month	(12-13) Year	(14-15)	(16-17)	(18-19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
		19																		
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PREGNANCY HISTORY: Smoking during pregnancy (cigarettes/day) None	Under 20	Over 20	Rubella during pregnancy Yes	No	Abdominal X-ray or pelvimetry Yes	No	HEALTH OF CHILDREN BORN DURING PAST 10 YEARS: Congenital Abnormalities (See Table* & list each by letter & number from left, e.g.-anencephaly = E 1 .)			Cancer or Leukemia Yes	No	Age at Onset	Diagnosis Site	Type	Death of Child Yes	No	Cause
(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42-43)	(44-45)	(46-47)	(48)	(49)	(50-51)			(52)	(53)	

*Table of Congenital Abnormalities:
A. cardiovascular: 1. atrial septal defect 2. ventricular septal defect 3. patent ductus 4. other
B. respiratory: 1. choanal atresia 2. diaphragmatic hernia 3. agenesis of lung 4. other
C. musculoskeletal: 1. achondrodysplasia 2. syndactyly 3. limb amputation 4. other
D. gastro-intestinal: 1. cleft palate or lip 2. imperforate anus 3. omphalocoele 4. other
E. central nervous system: 1. anencephaly 2. spina bifida 3. hydrocephalus 4. other
F. urogenital: 1. extrophy of bladder 2. hypospadias 3. undescended testicle 4. other
G. skin: 1. cavernous hemangioma 2. birthmark 3. nevus 4. other

Fig 2 ■ Reverse side of questionnaire.

sample of other dentists representing about 4% of the total American Dental Association membership of 121,068.

Methods

Questionnaires requesting information regarding health history and the number of hours exposed per week to anesthetic gases were mailed to members of the two dental societies (Fig 1, 2). Information also was sought from male members regarding the pregnancy history of their spouses. Less than 1% of the respondent population were women, and their responses are not analyzed in this report. The questionnaires were individually numbered, and as responses were received these were checked off of address lists supplied by the cooperating societies. Repeat mailings were sent to each of the nonrespondents. In all, three mailings were carried out. The data were edited as received and completed forms entered into a 360/67 IBM computer for storage and retrieval. Incomplete forms were returned to the respondent for correction.

Rates for spontaneous abortion (loss of the product of conception before the 20th week of pregnancy) were based on the number of spontaneous abortions per 100 women as reported by the male respondents for their spouses during the past ten years; therapeutic abortions were not considered. Congenital abnormality rates were based on the number of live-born babies with one or more abnormalities per 100 live-born babies born over the past ten years. Disease rates were based on the number of cases diagnosed within the past ten years per 100 male respondents. Rates were standardized and adjusted for both age and smoking in the analysis for spontaneous abortion and congenital abnormalities, and for age alone in the analysis for the various diseases. In the former calculations, age and smoking habit of the spouse at the time of pregnancy were applied, and for the latter, age of the respondent at the time of the survey. In calculating standardized rates for spontaneous abortion and congenital abnormality, the standard population used consisted of 30% smokers and 70% nonsmokers, with age distributions of 50% below 30 years of age, 40% in the age range of 31 to 37, and 10% over 37 years of age. For adjustment of disease rates, the standard population used for all groups had age distributions

of 40% below 40 years of age; 40% in the age range of 40 to 54; and 20% over 54 years of age. Significance tests, *P* values, were computed using one-sided tests against the alternative that exposed groups have higher rates.

Results were analyzed according to the anesthetic exposure of the respondent. Respondents who reported that they worked in dental surgery with anesthetics a minimum of three hours per week during the calendar year preceding their spouse's pregnancy were separated from those who reported no exposure to anesthetics. Individuals with intermediary exposure (less than three hours) were not included in the analysis. In the analysis for cancer, liver, or kidney disease, exposure to anesthetics was defined as at least one year's exposure, but not necessarily including the immediate year before onset of the disease. Respondents from both dental groups were combined into single "exposed" and "unexposed" groups since the effects of exposure to anesthetic gases proved similar.

Results

The response rate to the three questionnaire mailings is given in Table 1. The return rate of the mailings for the oral surgeons was 64.5% and that for the general dentists totaled 38.9%. Similar differences in questionnaire return rates were reported in an earlier study of operating room personnel in which the exposed group responded more completely than the control.[6]

The hours of exposure to anesthesia in the dental survey varied considerably between oral surgeons and the general practicing dentists (Table 2). The data indicate that whereas 87.9% of the oral surgeons have some exposure to anesthetics, only 27.6% of the general dentists are so exposed. For purpose of analysis, assignment to the exposure group was limited to those individuals exposed to anesthesia three or more hours per week, and in this category were included 74.8% of the oral surgeons and 20.2% of the general dentists.

Table 1 ■ Response rate to three mailings of the questionnaire.

	ASOS*		ADA*	
	No.	%	No.	%
First mailing	1.009	38.2	746	15.6
Second mailing	378	14.3	549	11.4
Third mailing	340	12.9	571	11.9
Total	1.727	65.4	1.866	38.9

*Percentages adjusted for questionnaires returned "address unknown." Total mailing for the ASOS was 2,642 and for the ADA, 4,797.

Table 2 ■ Hours of anesthetic exposure per week within each of the respondent groups.

Hours of exposure	ASOS		ADA	
	No.	%	No.	%
0	209	12.1	1,351	72.4
1-2	227	13.1	138	7.4
3+	1,291	74.8	377	20.2

The principal results of the study are shown in Table 3. These results indicate that the incidence of spontaneous abortion is increased about 78% in the spouses of the exposed dentists compared with the spouses of unexposed dentists. These differences are highly statistically significant ($P<0.01$). Congenital abnormality rates appear to be slightly higher in the spouses of exposed dentists than in the spouses of persons in the unexposed control group. These women show a 15% increase in fetal abnormalities over that found for the spouses of the unexposed dentists. Sample sizes are small, and the differences are not statistically different ($P=0.26$). The rate of cancer in the male respondents also appears greater in the exposed group than in the control group. The increase in cancer is 35% in the exposed respondents. Again, sample sizes are small, and the difference is not statistically significant ($P=0.26$). The incidence of liver disease was calculated after excluding cases of serum hepatitis to eliminate possible differences in exposure to blood and blood products. The incidence of liver disease was found to be increased 156% in the

Table 3 ■ Spontaneous abortion rates per 100 pregnancies, congenital abnormality rates per 100 live-born babies, and disease rates per 100 respondents in exposed versus unexposed dentists.

	Exposed dentists		Unexposed dentists		
	Sample size	Standardized rate ± SE	Sample size	Standardized rate ± SE	
Spontaneous abortion (spouses)	887	16.0±1.8	1,541	9.0±1.0	$P<0.01$
Congenital abnormalities	765	4.7±1.1	1,393	4.1±0.4	$P=0.26$
Cancer	1,631	0.69±0.26	1,326	0.51±0.18	$P=0.26$
Liver disease	1,528	5.9±0.4	1,249	2.3±0.4	$P<0.01$
Kidney disease	1,481	2.6±0.3	1,273	3.0±0.5	$P=0.74$

exposed group compared with the unexposed control group. This difference was highly statistically significant ($P<0.01$). Kidney disease rates between the two groups also were examined, but no noteworthy difference was apparent.

Discussion

From the survey of operating room personnel[6] and from the comparison of results for the various groups surveyed in this study, it is clear that the choice of a control group is extremely important. Unexposed dentists seem to be an excellent control group, but differential response biases and interpretation of the questionnaire, for exposed and unexposed respondents, might still explain some of the differences reported.

In the evaluation of the results of this survey, the influence of certain possible biases have been checked. Multiple logistic analyses have been carried out, correcting for additional variables that might be different and act differently in the exposed and unexposed groups. These variables, in addition to age and smoking, were the pregnancy history of the spouse and reluctance to respond to the survey (measured by the number of mailings required to elicit a response). The results of these more complex analyses strengthened the conclusion indicated in Table 3 regarding spontaneous abortion, and added additional weight to the suggestion that exposure of the male increases the risk of congenital abnormality in his live-born offspring.

The results of this study may be compared with the data previously obtained in the national study of exposed operating room personnel.[6] The slightly increased incidence of congenital abnormalities present in the spouses of those in the exposed group and the greatly increased incidence of liver disease among the exposed respondents are similar in magnitude to those seen for exposed male physician anesthetists. Similarly, the incidence of kidney disease, alike in exposed and unexposed groups, was also the same in anesthetists and pediatricians. However, the significant increase in spontaneous abortion found in the spouses of those in the exposed group and the slight increase in cancer rates among those in the exposed group were findings not seen in the survey of exposed male anesthetists.

In comparing this survey of dentists with the results obtained for physicians, one first notes the large differences in reporting rates. However, equally important may be the differences in the levels of exposure to waste anesthetic gases that are present between dentists and physician anesthetists. Although the total exposure in hours for the physician anesthetist is undoubtedly greater than that for either the oral surgeon or general dentist, the concentration of waste anesthetic gas present in the dental surgery is at least several times that found in the operating room. These concentrations result from the semiopen anesthetic techniques commonly used in dental surgery, including the nasal mask and throat pack, in contrast to the use of a tightly fitting face mask and sealed endotracheal tubes by the physician anesthetist. Of particular importance in this study is the evidence that establishes a relationship between the incidence of these health problems and exposure to the waste anesthetic gases. Both the general dentists and oral surgeons provide similar care to their patients in dental surgery whether or not local or inhalation anesthesia is used, yet separation of these individuals into a group exposed to anesthetic gases and one not exposed reveals significant differences in disease rates.

The apparent increased health hazards to the exposed dentist and his offspring strongly suggest that preventive measures should be taken. However, the provision of protection to the dentists from the hazard of anesthetic exposure poses a difficult problem. Unlike the hospital operating rooms, most air-conditioning systems used in dental surgery are of the recirculating type that provide continuing recirculation of the waste anesthetic gases. In addition, the use of a high flow of anesthetic gases in combination with the open mouth of the patient makes the application of scavenging techniques difficult. Nonetheless, our findings suggest that the health problem is a potentially serious one and that means must be sought to protect exposed personnel.

Several methods of using waste gas scavenging within dental surgery are currently under investigation. These include the use of individual, fresh air, breathing masks, the use of a controlled air flow pattern that rapidly evacuates the air immediately adjacent to the patient and clinician, and the use of an exhaust line attached to the exhalation part of the breathing circuit. Further information is also urgently needed to define those levels of exposure that may be considered safe for dental personnel. However, in the absence of this information, it seems prudent

to reduce exposure to the waste anesthetic gases to as low a level as possible by applying those scavenging techniques already available. The rapid development of more efficient scavenging systems for use in the dental surgery should have high priority.

Supported by Contract no. HSM-99-73-73, National Institute for Occupational Safety and Health, and in part by NIH Program Project GM-12527.

Successful completion of this study required the cooperation of many individuals including Mr. David Himmelberger who provided statistical and programming skill, Ms. Rosalie de la Torre who served as Stanford study coordinator, and Mr. Glenn Johnson who served as American Society of Anesthesiologists coordinator. Joseph K. Wagoner, SD Hyg, director of field studies and clinical investigation, National Institute for Occupational Safety and Health, and William M. Johnson, MD, former deputy director of field studies and clinical investigations, NIOSH, are acknowledged for their professional contributions to the study. The cooperation of the American Society of Oral Surgeons and the American Dental Association in making their membership lists available is acknowledged, as is the important contribution of each respondent.

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Foley's Footnotes

When one considers the number of dental advertisements published in this country in the 19th century and the number of lightly educated practitioners, one should not be shocked by the bare-boned wording of these three well-intended but bizarre notices: "Teeth extracted with great pains."—"Dentist O'Neill is in town to-day, pulling and filling the people's aches."—"Teeth pulled while you wait."

However, how can this Philadelphia flippancy of 1955 be other than vigorously damned: "If you have one tooth that gives you as much trouble as your wife's whole mouth, give me a trial."

For its brevity, boldness, reflected pride, and originality, I present a New Haven dental advertisement of 1880 as being truly antithetical to those nonprofessional blurts given above. F. Norton, dentist, advertised in the *Yale Literary Magazine:* "All operations in my line done with exactness and perfection." Of course, the phrase "in my line" and terms "exactness" and "perfection" will be regarded as questionable wording in our time, but for his day Dr. Norton revealed a feeling of professional pride and a good concept of obligation to his patients.

Gardner P. H. Foley