A Comparison of Dental Treatment Utilization and Costs by HMO Members Living in Fluoridated and Nonfluoridated Areas

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Abstract

Objectives: *To compare dental treatment experiences and costs in members of a health maintenance organization (HMO) in areas with and without community water fluoridation.* ***Methods:*** *HMO members with continuous dental eligibility (January 1, 1990 to December 31, 1995) who resided in Oregon and Washington were identified using administrative databases. Fluoridation status was determined by geocoding subscriber address. Measures were utilization of dental procedures, fluoride dispensings, and associated costs. Costs were based on nonmember fees, adjusted to 1995 dollar values. Data were analyzed using analysis of covariance, controlling for age and interactions.* ***Results:*** *About 85 percent of eligible members (n = 51,683) were classified as residing either in a fluoridated (n = 12,194) or nonfluoridated (n = 39,489) area. Mean age was 40.0 years; 52.3 percent were women. More than 92 percent of members had one or more dental visits. Community water fluoridation was associated with reduced total and restorative costs among members with one or more visits, but the magnitude and direction of the effect varied with locale and age and the effects were generally small. In two locales, the cost of restorations was higher in nonfluoridated areas in young people (<age 18) and older adults (>age 58). In younger adults, the opposite effect was observed. The impact of fluoridation may be attenuated by higher use of preventive procedures, in particular supplemental fluorides, in the nonfluoridated areas.* ***Conclusions:*** *These results are particularly relevant to insured populations with established access to dental care. Differences in treatment costs (savings) associated with water fluoridation should be estimated and included in future cost-effectiveness analyses of community water fluoridation.*

Key Words: fluoridation, cost, dental care utilization, dental restorations, health maintenance organizations

Introduction

Dental caries remains a prevalent disease. Nearly 80 percent of adolescents have had one or more carious lesions (1), and 93.8 percent of adults have evidence of treated or untreated caries (2). While optimal water fluoridation has long been known to reduce caries experience (3-6), by 1992 only 62 percent of the US community water systems were fluoridated, short of the relevant goal of at least 75 percent in *Healthy People 2000* (7) and *Healthy People 2010* (8). With the proliferation of fluoride technologies applied to individual patients, smaller differences exist in caries experience between community water fluoridated (CWF) and nonfluoridated (NF) areas (9). Given the changing epidemiological profile of caries, however, data are needed on the cost-effectiveness and health consequences of CWF and other fluoride technologies.

Cost-effectiveness analysis – assessment of the comparative impacts of expenditures on different health interventions (10) – can inform resource allocation decisions to improve health. One major evaluation aspect of any preventive program is to estimate the net cost or savings realized through preventing disease and reducing the need for treatment. Net dental treatment costs associated with prevention of caries should be included in the economic analysis of CWF programs. Estimates of net treatment costs should include the initial restoration, replacement costs, cast restorations, endodontic therapy, extractions, bridges, and so on (11).

CWF cost-effectiveness analyses have not typically included reduced caries treatment costs, thereby overestimating the marginal change in health care costs attributable to CWF (12). Cost-effectiveness guidelines are based on the appraisal of the performance of preventive programs (13,14), but no consensus has been reached on whether to include treatment savings or not (11), and very few estimates have been done of the potential cost savings associated with CWF.

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One study found that in adults aged 20-34 years with private dental insurance, CWF reduced disease but may or may not have reduced the use of restorative services (12). The researchers speculated that in CWF regions with a large number of dentists, less disease and more dentist competition might have resulted in supplier-induced restorative demand. Another study used epidemiological data from national surveys to model the reduction in dental treatment and associated costs. It found that the reduction in restorative care costs as a result of averted disease attributed to CWF exceeded the cost of water fluoridation in communities of any size (15). A third study found differences ascribable to caries prevalence and community size (16). A recent study estimated costs (and savings) associated with CWF in permanent teeth, including patients' time spent while obtaining care and the cost of CWF (17). While the results were robust under a variety of assumptions, these reports did not use actual treatment experience or longitudinal restorative cost data to estimate costs and/or savings.

The objective of this study was to identify the dental treatment experiences of persons living in CWF and NF areas and to evaluate differences in dental treatment costs using a 1990-95 dataset from a dental health maintenance organization (HMO). While the data collection was contemporary, data analyses and publication were unfortunately delayed for years.

Materials and Methods

Institutional review board approval was obtained for this data-only study.

Study Population and Its Environment. Kaiser Permanente Northwest region (KPNW) is a not-for-profit, federally qualified HMO that served about 162,800 dental plan members in 1990 in Northwest Oregon and Southwest Washington. The KPNW Dental Care Program (KPDCP) offers comprehensive preventive and restorative services. Dentists, who are not employees of KPDCP, contract their salaried services exclusively to KPDCP as a self-governing, independent professional group; they use their professional judgment in deciding what care to provide, within the guidelines set by the group.

Administrative data from dental HMO subscribers and their dependents (collectively, members) were included in the study if members: a) were continuously eligible for dental services from January 1, 1990 through December 31, 1995; and b) had the then-current subscriber residence address in the Portland, OR, metropolitan area (Clackamas, Multnomah, and Washington counties), Marion County, OR (primarily Salem), or Clark County, WA (primarily Vancouver), that could be classified as having a fluoridated or NF water supply (HMO administrative data sets provide only current address, precluding ascertainment of historical changes).

Fluoridated and NF Regions. Each of the three geographic locales contained both CWF and NF water districts, and we observed three levels of fluoridation compliance across the three locales. This variation was an important factor in designing the analyses, which evaluated the contribution of locale as well as fluoridation status to costs and number of procedures.

In Clark County, water districts with CWF (primarily Vancouver) consistently had fluoride levels within the optimum range of 0.8 to 1.3 parts per million (ppm).

In contrast, in Marion County water districts (primarily Salem), CWF optimum criteria for fluoridation were only intermittently met. For 3 of the 6 years of the study period, the percentage of days each year that the fluoride level in the water supply was equal to or greater than 0.5 ppm was less than 25 percent. In only 2 of the 6 years did this percentage exceed 50 percent, and on more than 300 days in 1993, fluoride levels were lower than 0.5 ppm.

The only fluoridated water district in the Portland metro locale is the Tualatin Valley, OR. Compliance there was moderately good: the percentage of days each year that the water was fluoridated ranged from 58 to 98 percent. During 5 of the 6 study years, water was fluoridated at optimum levels (between 0.5 and 1 ppm) on at least 76 percent of the days. Thus, this area was intermediate between Clark and Marion counties in fluoridation compliance.

Fluoridation Status. To determine the fluoridation status of members, addresses of KPDCP subscribers were provided to the Metro Data Resource Center (DRC) in Portland, OR. The DRC linked water provider information to each address (geocoded) using geographic information systems. Subscribers whose address was located within 100 feet of a city, county, or water district boundary were excluded ($n = 137$). Subscribers whose address was located in a water district with a known fluoridation status were assigned to that status group. Dependents of a subscriber were classified by the subscriber's residence address locale and fluoridation status.

Outcome Measures and Variable Acquisition. Outcome measures were dental services that fluoridation could directly influence, costs and number of procedures, including prescribed fluorides, derived from KPNW administrative, dental treatment, and outpatient pharmacy databases. These databases also were used to identify continuous membership and dental office visits.

Number of Procedures. The primary utilization measure was the number of procedures per member among those with any dental visits in the 6-year period (and hence nonzero costs). We separately examined counts of restorative procedures and two primarily preventive procedures – first, pit-and-fissure sealants and preventive resin restorations (S/PRR), and second, supplemental (other than over the counter) fluoride dispensings. To measure supplemental fluoride dispensings, the KPDCP list of products containing fluoride was compared with dispensing records to determine the number of members who had any dispensings of such products during the study period (either prescribed or administered in-office).

Costs. We used nonmember fees as the basis for setting costs of all procedures listed above. Nonmember fees were those that would have been charged a non-KPDCP member who used KPDCP services in the year that the procedure was carried out. Procedure fees for all years were converted to 1995 dollars using the dental component of the Consumer Price Index (CPI). Procedure codes in the treatment database for each member were linked to the procedure fees to obtain costs for dental services and per-visit costs. The cost of supplemental fluorides was based on nonmember product and dispensing fees and converted to 1995 dollars using the drug component of the CPI. We analyzed costs after applying a normalizing transformation, the natural logarithm (ln) of $x+1$, where x was the raw dollar amount, to correct for extreme skewing. In tables and figures, estimates were converted back from ln units to dollar units for ease of interpretation.

Data Analysis. Because the three geographic locales contain both CWF and NF water districts, we have a factorial design, which allows the evaluation of the interaction of locale and fluoridation status. Because the distribution of age differed between locales, we also entered age into the models as a covariate. All analyses were carried out using SAS 8.2 (SAS Institute, Inc., Cary, NC, USA).

We used analysis of covariance models to evaluate the impact of fluoridation, locale, and age (and their interactions) on costs and utilization, with error models that matched the three types of dependent variable. Transformed (normalized) cost data were modeled using ordinary least squares (PROC GLM). Proportions were analyzed using logistic regression, and the counts of number of procedures or visits were modeled using Poisson regression (PROC GENMOD for both).

Analysis of covariance has important assumptions that we tested (18) before settling on a final model. We evaluated the assumption that the relationship between age and each dependent variable was linear; if it was not, we planned to analyze a nonlinear function of age that more accurately represented the relationship (e.g., age-squared, age-cubed). We tested two homogeneity assumptions: a) that age has the same association with outcome in all of the six groups (three locales by two fluoridation statuses) and b) that the differences between NF and CWF areas were proportional across different locales. We set α at 0.20 in tests on interactions to reduce the probability of missing an interaction that would modify interpretation of the main effects. We set α at .05 for all other tests.

When a significant interaction indicated that the assumption of homogeneous effects was not met, we followed up with estimates of the means to understand the pattern of differences better. For an interaction between locale and fluoridation status, we compared means in fluoridated versus NF areas separately for each locale. In some cases, we also examined differences between locales within a fluoridation status. If there was an interaction between age and locale and/or fluoridation status, we estimated the predicted value of the dependent variable in the six cells at three arbitrarily selected values of age, in order to illustrate how costs varied as a function of age. We selected the mean: age 10, the midpoint of the youngest 10 percent, and age 80, about the middle of the oldest 10 percent.

Results

Sample Identification. We identified 60,732 eligible members, each of whom was linked to the address of an HMO subscriber ($n=28{,}887$). Duplicate, post office box, and "in care of" addresses, and addresses outside the study locales were eliminated, leaving 25,685 addresses. DRC was able to place 24,729 unique addresses in the water districts, which represented 51,683 dental HMO members who met all of the eligibility criteria. Table 1 shows the sample sizes by locale and fluoridation status. As of December 31, 1995, age ranged from 5 to 98 years (mean = 40.0, standard deviation = 20.3). We grouped several youngsters born on January 1, 1990 with 6-year-olds. KPNW members were predominantly (over 90 percent) a White population, consistent with the KPNW service area, and 52.3 percent were female.

Table 1
Proportions of Participants with One or More Dental Visits by Locale and Fluoridation Status, at Selected Ages

Locale	Estimated at member age	Proportion with >1 visit: NF	CWF	$P<$*
Portland metro		$n=33{,}657$	$n=3{,}405$	
	10	0.95	0.96	0.34
	40	0.92	0.94	0.02
	80	0.85	0.88	0.08
Marion County		$n=1{,}568$	$n=4{,}006$	
	10	0.96	0.96	0.44
	40	0.95	0.94	0.31
	80	0.91	0.91	0.85
Clark County		$n=4{,}264$	$n=4{,}783$	
	10	0.98	0.95	0.01**
	40	0.94	0.92	0.01**
	80	0.83	0.86	0.07

* P-value for difference in age-adjusted proportions between NF and fluoridated, within locale, at the specified age; ** $P<0.0001$.
CWF, community water fluoridated; NF, nonfluoridated.

Table 2
(A) Total Six-Year Costs and (B) Number of Visits for Members with One or More Visits

A. Total costs

Locale	Estimated at member age	NF ($)	CWF ($)	Difference ($)†	Model 1 *P*<‡	Model 2 *P*<¶
Portland metro		$n = 30{,}967$	$n = 3{,}185$			
	10	1,054	1,108	(54)	0.01	0.91
	39	1,224	1,300	(76)	0.24	0.01*
	80	2,101	2,253	(152)	0.07	0.73
Marion County		$n = 1{,}482$	$n = 3{,}763$			
	10	1,097	1,086	11	0.08	0.95
	39	1,236	1,200	37	0.50	0.21
	80	1,882	1,686	196	0.01	0.01
Clark County		$n = 4{,}006$	$n = 4{,}404$			
	10	1,261	1,130	131	0.01*	0.01
	39	1,408	1,287	121	0.06	0.74
	80	2,059	1,978	81	0.12	0.44

B. Number of visits (same sample as A)

Locale	Age	NF	CWF	Difference†	Model 1 *P*<‡
Portland metro					
	10	12.7	13.5	−0.8	0.04
	39	14.3	14.9	−0.5	0.04
	80	20.3	20.9	−0.6	0.47
Marion County					
	10	12.6	12.0	0.7	0.28
	39	13.1	13.6	−0.5	0.26
	80	18.9	16.6	2.3	0.04
Clark County					
	10	14.4	13.0	1.4	0.01
	39	14.7	14.2	0.4	0.17
	80	20.7	19.3	1.4	0.16

P-values are for the difference in age-adjusted proportions between NF and CWF, within locale, at the specified age (and in Model 2, number of visits).

* $P < 0.0001$.

† Difference is NF – CWF, negative differences (in parentheses) indicate CWF > NF. Differences may not match the NF mean – CWF mean because of rounding.

‡ Model 1 includes only age and age^2 as covariates.

¶ Model 2 includes age, age^2, and ln(number of visits) as covariates.

NF, nonfluoridated; CWF, community water fluoridated; ln, natural logarithm of cost + $1.

Tables 1 to 6 present the results of modeling for the various outcome measures. The means presented in the tables are model-based least-squares estimates. The *P*-values in Tables 1 to 6 are for the difference between members with CWF and those with NF in the specified locale; those that we judged significant are underlined. We present the predicted value of the dependent variable at three levels (low, mean, high) of age in order to illustrate how the costs or utilization varied with age. Because the subsamples vary in size and membership, they also vary in mean age.

Proportion of Members with a Dental Visit. Table 1 shows the proportion of members by locale, fluoridation status, and selected ages who had one or more dental visits during the study period ($n = 51{,}683$). The relative proportion of members with a visit at various ages differed significantly between the six combinations of locale and fluoridation status (i.e., the three-way interaction of age, locale, and fluoridation status was significant, $P < 0.09$). The *P*-values for contrasts between NF and CWF in the three locales at ages 10, 40 (the mean overall subjects), and 80 are given in the last column of Table 1. In the Portland metro area, the proportion with one or more visits was generally higher among Portland metro members with CWF than with NF, but this difference was significant only at age 40 ($P < 0.02$). In Marion County, the contrasts were not significant at any age. In Clark County, more members with NF had a visit than those with CWF overall, but the difference between fluoridation status groups is significant only at ages 10 ($P < 0.001$) and 40 ($P < 0.001$).

Cost of Dental Care. Table 2A shows the total costs over the study period for members who had one or more visits ($n = 47{,}807$), by locale, fluoridation status, and age. Initially (Model 1), we examined only age as a covariate. Age has a quadratic relationship with ln(costs + 1); that is, the rate of increase in costs over changing ages was relatively small before about age 40, then climbed more rapidly at older ages. There were significant three-way interactions between age-squared, locale, and status ($P < 0.01$) and between age, locale, and status ($P < 0.001$). We report predicted costs and P-values for contrasts at ages 10, 39 (the mean for this sample), and 80, which reveal the inconsistent differences between CWF and NF across locales and ages, indicated by the significant interactions. Portland metro had higher costs in CWF areas than in NF areas, the opposite of Marion County and Clark County, although not all differences are significant. Differences between CWF and NF in total costs were significant only among children (age 10) in Portland metro ($P < 0.01$) and Clark County ($P < 0.001$) (but in opposite directions), and in Marion County only in elderly members (age 80, $P < 0.01$).

Number of Dental Visits. Table 2B shows the effects on visit counts for the same factors and subject sample as in Table 2A. As for costs, age had a quadratic association with visit count, with a parallel pattern of higher frequency of visits at older ages. The three-way interactions involving age-squared and age were significant at $\alpha = 0.20$ ($P < 0.11$ and 0.09, respectively). Fit statistics indicated overdispersion of the data (higher variance than expected for a Poisson distribution), and standard errors were scaled using the deviance (generalized Poisson). We found the same overall pattern of differences in visit counts that we found in modeling costs (Table 2A). In Portland metro, members in the NF areas had fewer visits than those in the CWF areas; this was significant only at ages 10 and 39. In Marion and Clark counties, the pattern generally showed more visits in NF than CWF areas, but these contrasts reached significance

Table 3
(A) Proportion of Members with One or More Restorative Procedures and (B) Counts of Restorative Procedures among Members with One or More Dental Visits

A. Proportion with restorative treatment

Locale	Age	NF	CWF	Difference†	$P<$
Portland metro	$n = 30{,}967$	$n = 3{,}185$			
	10	0.62	0.64	−0.02	0.35
	39	0.84	0.84	0.00	0.83
	80	0.81	0.86	−0.05	0.01
Marion County	$n = 1{,}482$	$n = 3{,}763$			
	10	0.69	0.64	0.05	0.03
	39	0.84	0.80	0.04	0.01
	80	0.83	0.84	−0.01	0.67
Clark County	$n = 4{,}006$	$n = 4{,}404$			
	10	0.70	0.66	0.04	0.02
	39	0.87	0.85	0.02	0.01*
	80	0.78	0.80	−0.02	0.47

B. Estimated mean number of restorative procedures (same sample as A)

Locale	Age	NF	CWF	Difference†	$P<$
Portland metro					
	10	4.15	4.18	−0.03	0.80
	39	6.61	6.46	0.15	0.26
	80	12.79	11.96	0.83	0.04
Marion County					
	10	4.24	4.13	0.11	0.55
	39	6.36	6.01	0.35	0.10
	80	11.28	10.20	1.08	0.02
Clark County					
	10	5.18	4.73	0.45	0.01
	39	8.00	7.08	0.92	0.01**
	80	14.79	12.52	2.27	0.01**

* $P < 0.001$; ** $P < 0.0001$.
† Difference is NF – CWF, negative value indicates CWF > NF.
CWF, community water fluoridated; NF, Nonfluoridated.

Table 4
Six-Year Costs for Restorative Procedures among Members with One or More Restorative Procedures

Locale	Age	NF	CWF	Difference*	$P<$
Portland metro		$n = 24{,}418$	$n = 2{,}513$		
	10	226	268	(42)	0.01
	41	361	330	31	0.01
	80	550	483	67	0.15
Marion County		$n = 1{,}199$	$n = 2{,}892$		
	10	255	213	42	0.06
	41	302	358	(56)	0.01
	80	503	395	107	0.07
Clark County		$n = 3{,}275$	$n = 3{,}504$		
	10	293	237	55	0.01
	41	407	388	20	0.18
	80	590	523	67	0.26

* Difference is NF – CWF, negative differences (in parentheses) indicate CWF > NF. Difference may not match NF mean – CWF mean because of rounding.
CWF, community water fluoridated; ln, natural logarithm of restoration cost; NF, nonfluoridated.

Table 5
Proportion Receiving S/PRR in Members Ages 6 to 17 Years Old with One or More Dental Visits

Locale	Age	NF	CWF	Difference†	$P<$
Portland metro		$n = 6{,}706$	$n = 747$		
	8	0.51	0.59	−0.08	0.02
	12	0.70	0.81	−0.11	0.01**
	16	0.51	0.70	−0.19	0.01**
Marion County		$n = 298$	$n = 822$		
	8	0.57	0.65	−0.08	0.17
	12	0.76	0.78	−0.02	0.47
	16	0.57	0.56	0.01	0.71
Clark County		$n = 1{,}003$	$n = 986$		
	8	0.73	0.67	0.06	0.08
	12	0.89	0.85	0.04	0.01*
	16	0.84	0.76	0.08	0.01

* $P < 0.001$; ** $P < 0.0001$.
† Difference is NF − CWF, negative value indicates CWF > NF.
CWF, community water fluoridated; NF, nonfluoridated.

only at age 80 in Marion County and at age 10 in Clark County.

We hypothesized that differences in the number of dental visits might account for the differences in costs noted in Table 2A. Therefore, we added visit count as a covariate in the costs model (Model 2). The three-way interactions of age-squared, age, and visit count with locale and status are all significant at $\alpha = 0.20$ ($P < 0.01$, 0.01, and 0.08, respectively). In Portland metro, the effect of adjusting for visit count was a shift in the age at which significant differences were observed, from age 10 ($P < 0.91$) to age 39 ($P < 0.001$). No other change in the pattern of significance was observed.

Prevalence and Volume of Restorative Procedures. Table 3A shows the proportion of members with one or more visits who had a restoration ($n = 47{,}807$). The association of this proportion with age is quadratic; in this outcome measure, the proportion having visits increased from youth to middle age, then either stopped increasing or decreased in older members. The three-way interactions were not significant, but all two-way interactions were significant (locale × status, $P < 0.001$; age × status, $P < 0.17$; age × locale, $P < 0.03$; age-squared × status, $P < 0.08$; age-squared × locale, $P < 0.02$). In Portland metro, proportions receiving any restorative treatments were the same or higher in the CWF areas than in the NF areas, but only among older members is this significant (age 80, $P < 0.01$). In contrast, in Marion and Clark counties, members aged 10 and 39 (the mean for this sample) in NF areas were significantly more likely to have a restoration than were members with CWF (see Table 3A for P-values); at age 80, the NF and CWF areas did not differ.

The number of restorative procedures (Table 3B) in the same sample was significantly higher among older members living in the NF areas in all locales. In Clark County, the difference (NF > CWF) was significant at ages 10 and 39 also. The form of the association with age was linear (increasing steadily with age), and the three-way interaction was not significant, so only two-way interactions with age were included in the final model (locale × fluoridation status, $P < 0.01$; age × locale, $P < 0.05$; age × status, $P < 0.12$). The fit statistics indicated overdispersion of the data, and the standard errors were scaled using the deviance (generalized Poisson).

Cost of Restorative Procedures. We evaluated whether costs of restorative procedures were related to fluoridation status in members who had at least one restoration ($n = 37{,}801$). Figure 1 displays mean restorative costs [estimated on ln (restoration cost) and converted back to dollars] on age deciles calculated in the whole subsample. Decile points close together indicate a high density of members in that age range, whereas those far apart indicate that there are relatively few members in that age range. As the figure shows, the form of the association with age appears to be cubic, with decrease from early years to teens, increase during the middle years, and decrease or flattening late in life. The three-way interactions of locale and status with the three age terms were all significant (age-cubed $P < 0.001$, age-squared $P < 0.001$, and age $P < 0.001$). As shown in Table 4, model-based means at ages 10, 41 (the mean for this subsample), and 80 indicate a complex pattern. In Portland metro, the pattern of differences between NF and CWF areas is significant but inconsistent at ages 10 (CWF > NF) and 41 (CWF < NF). In Clark County, only at age 41 was there a significant difference (CWF > NF). In Marion County, significance was seen only at age 10 (CWF < NF). The oldest members had the highest restorative costs and the largest NF–CWF differences; however, with small ns and larger standard errors, fluoridation status did not contribute a significant effect in any locale. We observed the same pattern of results when we excluded S/PRR from restorative costs.

S/PRR. Table 5 shows the association between age and proportion receiving S/PRR in the age range 6 to 17. The association of age with S/PRR is quadratic. Use of S/PRR peaked at about ages 12-14 and then declined among older teens. No two-way or three-way interactions involving age-squared significant, although age-squared by itself was significant ($P < 0.0001$). The three-way interaction involving age was significant ($P < 0.03$). In Portland metro, significantly more children in the CWF area received S/PRR than in the NF area (age 8 $P < 0.01$, age 12 $P < 0.001$, age 16 $P < 0.001$). The opposite pattern

Table 6
Supplemental Fluoride Dispensing among Child Members with One or More Dental Visits

	NF			CWF		
Locale/age group	*n*	Proportion with 1+ dispensings	Mean (SD) number of dispensings*	*n*	Proportion with 1+ dispensings	Mean (SD) number of dispensings*
Portland metro						
6-11	2,734	0.52	3.8 (4.2)	322	0.22	2.8 (3.4)
12-17	3,972	0.14	2.8 (3.7)	425	0.04	2.9 (3.5)
Marion County						
6-11	120	0.36	3.1 (2.8)	338	0.07	1.8 (1.3)
12-17	178	0.12	1.3 (0.9)	484	0.03	1.3 (0.6)
Clark County						
6-11	387	0.27	2.6 (2.8)	394	0.12	2.8 (3.2)
12-17	616	0.07	2.9 (3.5)	592	0.02	2.6 (3.4)

* Among members with one or more dispensings.
CWF, community water fluoridated; NF, nonfluoridated; SD, standard deviation.

was found in Clark County (significant at ages 12, $P < 0.001$, and 16, $P < 0.01$), which also had a markedly high prevalence of S/PRR use overall. In Marion County, the NF–CWF difference was not significant at any age.

Supplemental Fluoride Dispensing. Among members who had one or more dental visits ($n = 47{,}807$), about 7 percent in the NF areas and 2 percent in the CWF areas had at least one supplemental fluoride dispensing. Table 6 shows the percentage of members in the 6 to 11 and 12 to 17 age groups who received supplemental dispensings, and the mean number of dispensings. Less than 2 percent of members over 18 years of age received any dispensings. In the NF group, 48.5 percent of 6- to 11-year-olds and 12.8 percent of 12- to 17-year-olds received one or more supplemental dispensings. In the CWF group, 13.6 percent of 6- to 11-year-olds and 2.9 percent of 12- to 17-year-olds received one or more supplemental dispensings. Among members with NF water who received one or more dispensings, means ranged from 3.82 dispensings for 6- to 11-year-olds in Portland metro to 1.29 for 12- to 17-year-olds in Marion County. The cost of supplemental dispensing was small – less than 0.1 percent of total costs.

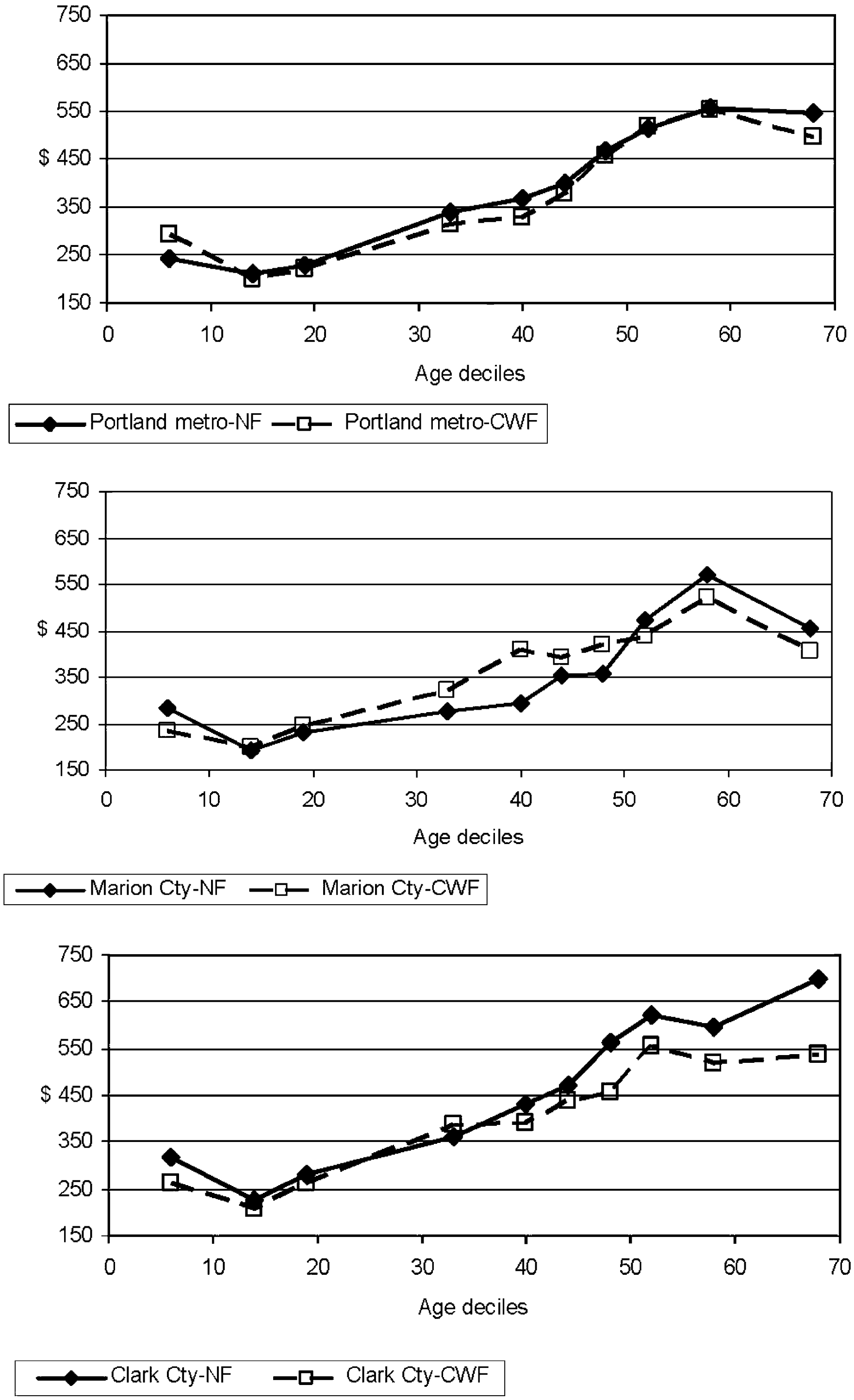
Preventive Procedures and Restorative Services. We evaluated whether a) the number of restorative procedures and b) restorative costs in children (ages 6 to 11 or 12 to 17) with one or more restorations could be predicted by fluoride dispensings or placement of S/PRR. These two models (not shown) controlled for fluoridation status and locale. We found that S/PRR was significantly associated with the number of restorations in both the 6- to 11- and 12- to 17-year-old groups ($P < 0.001$). However, the direction of the association was the opposite of what we would have expected – in every locale and fluoridation status, children with S/PRR had more restorations. Costs were not consistently higher in NF than CWF areas. There were significant two- and three-way interactions in all four models, making it difficult to generalize the specific contribution of these interactions beyond confirming the overall substantial association with S/PRR use.

Discussion

This project evaluated the impact of CWF on treatment and associated costs for a group of HMO members in the US Northwest between 1990 and 1995. In terms of total costs of dental treatment (Table 2A), Portland metro had lower treatment costs for the NF area, while the other two areas showed costs marginally higher for the NF status. For the intermittently fluoridated Marion County and the consistently fluoridated Clark County, CWF was generally associated with lower costs.

The ordering of treatment cost and utilization in CWF areas was not consistent with their ordering on compliance with intended fluoridation levels. The fact that Clark County, the most reliably fluoridated locale, often had the highest costs overall, the highest number and cost of restorative procedures, and the highest number of S/PRR (Tables 2A, 3B, 4, and 5) suggests that characteristics of members in these communities rather than fluoridation of water may be the primary driver of dental utilization. This is consistent with the overdispersion observed in counts of visits and of procedures, which can result when unobserved variables (i.e., important predictors of utilization) are missing from a model. Theoretically, the variance should equal the mean of a Poisson-distributed variable. In these data, however, the variance was much larger. One possible way to improve model fit is to add covariates that might account for more of the variance. It was beyond the scope of the present study to identify these, and so this remains a potentially fruitful area of inquiry. Candidates for inclusion as covariates include socioeconomic status (SES), chronic health conditions, and long-term use of medications leading to salivary gland hypofunction.

Figure 1
Age group breakout of restorative costs by locale and fluoridation status (exponentiated average natural logarithm of restorative costs). CWF, community water fluoridated; NF, nonfluoridated



Dentists' decisions on treatments and preventive services may also be affected by knowledge of the member's home fluoridation status. The extent of this effect was beyond the scope of this data-only study. The fact that dentists were all members of one group-model practice seems likely to ameliorate differences in practice decisions and thus minimize such impact.

Differences in caries experience between NF and CWF locales may have been diluted by variations between NF and CWF groups with respect to two preventive therapies. First, far more children in NF areas received one or more supplemental fluoride dispensings than did those in CWF areas (Table 6). The fluoride treatments received by children in NF areas could thus reduce the experience of caries and lessen the differences between NF and CWF. Such treatments also could signal better knowledge and behaviors related to dental and general health in their recipients or their families. Also, the application of S/PRR among members 6 to 17 years of age was dramatically greater than that reported in national surveys (19) – 60.6 percent in the NF regions and 70.5 percent in the CWF regions had at least one S/PRR. Differences between NF and CWF areas for S/PRR were inconsistent between locales, however. This situation may be partly attributable to some pediatric dentists who were particularly aggressive in their use of S/PRR during this time period. As indicated earlier, children with S/PRR had more restorations than those without S/PRR for each combination of locale and fluoridation status; hence, the use of S/PRR may depend to a large extent on observed caries risk regardless of fluoridation status, as previously reported (20).

In the CWF area of Clark County, where fluoridation compliance was good, overall costs were lower than in the NF area of Clark County. The same relationship held within Marion County, although the effect of fluoridation here was only marginally significant when not controlling for number of visits. Marion County differs from Clark County in the age at which the impact of water fluoridation is strongest: in Marion County it is in the oldest members, whereas in Clark County it is in the youngest members. In Portland metro, there was no evidence of a beneficial effect of fluoridation on total costs; in fact, costs were generally higher among members living in the CWF than in the NF districts of the metropolitan area. (However, as noted, the Portland metro area's CWF compliance with guideline levels was not optimal.)

Across the three locales, the overall differences in total costs with one or more dental visits between the CWF and NF areas (NF – CWF) ranged from *negative* \$152.31 (Portland, age 80) to \$196.02 (Marion County, age 80). (Note that *negative* in this context connotes the direction of the relationship between CWF and NF – see table legends). The cost of the supplemental fluoride dispensing was not included in the comparisons of total dental cost. If included, the difference in mean total cost per person with one or more dental visits would increase by \$0.94 over the 6-year period. Restorative cost differences (NF – CWF) per member with at least one dental visit over the study period ranged from *negative* \$55.94 (Marion County, age 41) to \$107.26 (Marion County, age 80). Taking into consideration the varying impact of age and locale, it seems reasonable to conclude that, as a general rule, costs were lower in the fluoridated areas.

As expected, total restorative costs increased with member age. The youngest and oldest members in the CWF areas had lower restorative costs and lower overall costs than same-age members in NF areas. Of note, in the older half of our sample (ages 43 to 98), mean difference in costs between the CWF and NF areas increased steadily and was highest in the 10th decile, centered at age 75 (NF > CWF, about \$75, unweighted means across locales on deciles of age, Figure 1). The higher costs in older adults probably were associated with several factors, including use of anticholinergic medications, gingival recession and emergence of root caries, and impaired ability to practice self-care derived from frailty and illness in the oldest members (those over 90, for instance). We had no diagnostic codes available to investigate these possibilities, but against these risk factors, fluoridation appears to have some protective effect.

Various methodological considerations suggest that our findings may not be directly generalizable to the overall US population. The participants were primarily a relatively stable group in terms of employment. Having health insurance in the United States, in particular dental insurance, greatly depends on having employment. About 92 percent of members had one or more dental visits during the study period, with an average of more than two visits/year. Given what is known from national surveys, this population may be at relatively lower risk for dental disease and is likely to have higher-than-average dental utilization. (Generally speaking, the effect of CWF may be larger on persons with less stable employment and housing and lower SES.) Thus, if CWF were to have an effect on dental disease in an HMO population, one might expect the effect to be small.

This study was further limited by having available HMO pharmacy data restricted to what was already available for other purposes. While clinical records and diagnostic criteria were not standardized, quality audits and guidelines were in place. Because only disease recorded and/or treated can be ascertained, early or subclinical stages of disease may not have been recorded.

Another caveat is that our data do not capture actual time spent living in a particular water district (whether CWF or NF) because our administrative records included only members' current address. (Taking this discussion to the extreme, we could argue that water fluoridation status of school or place of work might differ from that of home, but the impact of this unknown factor is impossible to gauge in the current study design.) However, there may not have been much moving between water districts as this sample of HMO members with stable dental benefits over 5 years are also unlikely to have moved very far during this period. We are aware that fluoride levels fluctuated over time and varied between locales. However, the CWF areas in the three locales were not ordered consistently with the level of fluoridation compliance, indicating that such compliance accounts for little of the variation observed between locales. Examining the reasons for the fluoride-level fluctuation over time and across locales is beyond the scope of the present study.

A strength of our sample and our study is that data from a group-model HMO are likely to exhibit less variation in clinical decisions, patients' deferral of needed treatment because of out-of-pocket cost, and potential for overtreatment decisions than data from other systems of organizing and financing dental care – the opposite of limitations noted/assumed in previous studies (17,21). Furthermore, use of bottled water was much less popular in the 1990s, and thus the relative importance of this factor in overall exposure to CWF in the 1990s was probably less important then, compared with what it is today. Another strength is that although these data represent costs and utilization that occurred more than a decade ago, the practice of dentistry, such as the availability of effective preventive treatment, has varied relatively little since then. There has been sparse research addressing this question in a sample of comparable size in the United States.

In conclusion, we found evidence that CWF was associated with reduced total and restorative costs among members with one or more dental visits, particularly in older adults. The effect we observed was generally small, likely because of this insured population's access to care and the higher use of preventive procedures, in particular supplemental fluorides, in the NF areas. Differences in treatment costs (savings) associated with CWF should be estimated and included in future cost-effectiveness analyses of CWF. Direct cost of CWF, based on equipment replacement costs, was estimated to be ~$0.67 person/year in 1989 and ranged from $0.15 to $1.53 (converted to 1995 dollars) (22). Reductions in dental treatment costs in the CWF areas compare favorably with the estimated costs of CWF (15,23-25), suggesting that CWF may in fact have been cost saving at the time the study was carried out.

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