



Association of Nationwide Water Fluoridation, changes in dental care legislation, and caries-related treatment needs: A 9-year record-based cross-sectional study

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ARTICLE INFO

Keywords:

Water fluoridation
Dental care legislation
Dental treatment needs
Socioeconomic status

ABSTRACT

Objectives: The implementation of Nationwide Water Fluoridation in Israel in 2002 led to a significant reduction in caries among children. However, this practice was discontinued in 2014 due to a change in legislation. In 2010, as part of the Israeli National Health Insurance Law, free dental care for children under 10 years of age was legislated. This policy was gradually extended to include adolescents under 18 years of age in 2018. We examined the association between these efforts and changes in the caries-related treatment needs of young adults over the course of two decades.

Methods: This cross-sectional study analyzed data on the need for dental restorations, root canal therapy, and extractions that were retrieved from dental records of 34,450 soldiers recruited into military service between 2012 and 2021. These data were cross-matched with the subjects' year of birth to determine whether the implementation of water fluoridation, dental care legislation, or both were associated with changes in the need for and provision of dental care. Sociodemographic data, including sex, age, socioeconomic cluster (SEC), intellectual capability score (ICS), body mass index, and place of birth, were also extracted.

Results: A multivariate generalized linear model (GLM) revealed that male sex, older age, low ICS, and low SEC were significant predictors for greater caries-related treatment needs ($P < 0.001$). Our findings indicated that subjects exposed to fluoridated water during their childhood had significantly lower rates of caries-related treatment, regardless of access to free dental care.

Conclusion: Mandatory water fluoridation was associated with significantly lower caries-related treatment needs while national dental health legislation providing free dental care to children and adolescents was not. Therefore, we suggest that water fluoridation should be continued to maintain the observed reduction in treatment needs.

Clinical significance: Our findings provide support for the effectiveness of water fluoridation in preventing caries, whereas the impact of free dental care programs focused on clinical intervention remains to be determined.

1. Introduction

Worldwide caries-related treatment needs are still high and are even increasing as a result of factors such as population growth and increased longevity, as well as changes in diet [1]. Many researchers claim that the most effective way to prevent caries at the community level is water fluoridation due to its ability to reach and affect large proportions of the population [2,3]. The efficacy of fluoridation is greatest for the

deciduous dentition, to a lesser extent for the mixed dentition, and has least impact on the permanent dentition [4]. Mandatory water fluoridation is particularly important to people of low socioeconomic status among whom the caries burden is especially high [5]. Israel implemented mandatory fluoridation legislation in 2002, enabling 75% of the population to enjoy the benefits of fluoridated water, a move that later resulted in a dramatic decline in caries experience among children [2]. In 2010, legislation for reforming dental care for children was passed,

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<https://doi.org/10.1016/j.jdent.2023.104550>

Received 17 March 2023; Received in revised form 6 May 2023; Accepted 15 May 2023

Available online 15 May 2023

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adding dental care to the basket of free services provided under the National Health Insurance Law. Coverage of children and adolescents has gradually been broadened and now extends from birth to age 18 years [6].

The purpose of this study was to compare the caries-related treatment needs of young adults who were not exposed to water fluoridation or dental care reforms, with young adults within the same population who were exposed to water fluoridation either alone or in combination with dental care reforms.

2. Materials and methods

This study was approved by the Israeli Defense Forces (IDF) Institutional Review Board (#2190–2021). This ecological record-based cross-sectional study was conducted on a cohort of individuals born between 1985 and 2003 who had been recruited into mandatory military service during the 9-year period between 2012 and 2021. None of the participants had a history of or a current significant systemic illness. Further information regarding the methods used for data collection can be found in our previous article [5].

2.1. Dependent variables

Data on three dependent variables were digitally collected: 1. number of teeth requiring restorations, 2. number of teeth requiring root canal treatment (RCT), and 3. number of extractions required due to caries. These data were retrieved from dental treatment plans made during the first 4 weeks of service as part of the mandatory preliminary medical examinations. The treatment plans were made for each of the participating recruits after a clinical examination followed by two bitewing radiographs. Appropriate periapical radiographs were also taken in cases of deep caries or former endodontic treatment. The quality of the treatment plans was checked periodically by regional military chief dental surgeons. Because our goal was to utilize the largest possible sample size, and since our subjects were free of significant chronic illnesses, we had only a few exclusion criteria. Only individuals who were regularly taking medication or who declined to have their radiographs taken were excluded from the study.

2.2. Independent variables

Demographic independent variables were derived from the IDF's recruitment database and included age, sex, place of birth (Israel or elsewhere), body mass index (BMI), socioeconomic cluster (SEC), and intellectual capability score (ICS). SEC was determined by the place of residence and is ranked 1–10 by the Israel Bureau of Statistics (10 being the highest SEC) [7]. The ICS is an initial psycho-technical evaluation and it is scored on a 9-point scale (10–90 with 10 point increments). It is carried out during the pre-draft screening, and includes verbal abstraction and categorization, concept manipulation, and mathematical knowledge [8].

In order to evaluate the association between dental treatment needs, national water fluoridation and the initiation of free dental coverage for children, we divided the study population into three groups according to year of birth. The Group A recruits were born after 2001 and enjoyed both fluoridation and free dental care, the Group B recruits were born between 1996 and 2000 and enjoyed water fluoridation at a young age but not free dental care, and the Group C recruits were born in and before 1994 and enjoyed limited benefits of national fluoridation (started in 2002) and none of free dental care reforms. Summary of the study groups and their exposures is presented in Table 1.

2.3. Statistical analyses

All statistical analyses were performed with IBM SPSS software (version 28). The level of significance was set to *P* value <0.05. The

Table 1
Summary of the study groups and their exposures.

	Water fluoridation	Dental care reform
Group A (Born after 2001)	Yes	Yes
Group B (Born 1994–2000)	Yes	No
Group C (Born before 1994)	No	No

univariate analyses included descriptive statistics given as means and standard deviations for continuous variables, and distributions given as percentages for categorical variables. Comparisons of means were by the Mann-Whitney and Kruskal-Wallis tests (for the a-parametric distributions). The Spearman correlation coefficient was calculated for linear correlation evaluations. For the multivariate analyses, a generalized linear model (GLM) was built to standardize the independent variables and to predict dental treatment needs. Independent variables that were found significant in the univariate analyses were entered into the multivariate model.

3. Results

The data analyzed in the current study were retrieved from the files of 34,450 subjects, the majority of whom (91.3%) were males, with a mean age of 18.94±0.82 years (range 17.7–29.62). Their mean BMI was 22.43±3.97 and their median ICS was 50 (range 10–90). Most of them (91.1%) were born in Israel, 2.5% in the former USSR, 2.1% in North America, 1.6% in Ethiopia, and 2.8% in other countries. The mean number of teeth requiring restorations was 1.72 ± 2.39 per subject, RCTs 0.06 ± 0.35 and extractions 0.04 ± 0.26. Associations between year of birth, sex, place of birth, and treatment needs are presented in Table 2. Association between ICS, SEC, BMI, age, and treatment needs are presented in Table 3.

A multivariate GLM analyses revealed that male sex, older age, low ICS, and low SEC were all predictors for more numerous caries related restorative treatment needs (*P* < 0.001, Table 4). Similar multivariate analyses for RCTs and extractions as the dependent variables were conducted and revealed similar results (data not shown). This analysis revealed that those born earlier than 1994 (Group C, no water fluoridation, no dental care reform) had significantly more (*P* < 0.001) treatment needs in all three categories than groups A and B. The other two study groups did not differ significantly in terms of RCTs and required extractions, but there was a significant difference in the number of caries related required restorations: there were significantly more in the group that was born in and after 2001 (Group A, who enjoyed both fluoridation and free dental care) (*P* = 0.049, Table 4).

4. Discussion

Our findings of this 9-year cross-sectional record-based study revealed an association between caries-related treatment needs and the provision of nationwide water fluoridation, but no comparable influence of the introduction of nationwide free dental care reform for children and adolescents.

Oral pathologies, caries among them, cause pain, infection, and reduced quality of life for billions of people worldwide [9]. Caries cannot be "treated away" by drilling and placing a restoration, but rather require prevention or detection in early stages in order to enable a more conservative and less complicated treatment [10]. Our data clearly showed an association between low SEC and greater treatment needs. This association comes as no surprise and is consistent with the literature [11,12]. The same can be said about the association between older age and greater treatment needs as reported by others [13,14].

Our results demonstrated a significant decrease in dental treatment needs between subjects born in and before 1994 (Group C) and subjects born in and after 1996 (Groups B and A). We assume that the major reason for this difference is the introduction of nationwide water

Table 2

Association between year of birth, sex, place of birth, and caries related treatment needs.

		N	Number of teeth in need of restorations		Number of teeth in need of RCTs		Number of teeth in need of extractions	
			Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value
Study group (according to year of birth)	Group A (+ F ^a , + R [#])	13,937	1.53 (2.24)	<0.001 ^a	0.05 (0.29)	0.001 ^a	0.03 (0.24)	<0.001 ^a
	Group B (+ F ^a , - R [#])	7060	1.57 (2.24)		0.06 (0.34)		0.04 (0.26)	
	Group C (- F ^a , - R [#])	10,581	2.06 (2.63)		0.07 (0.43)		0.05 (0.29)	
Sex	Female	2991	1.30 (2.03)	<0.001 ^b	0.04 (0.29)	<0.001 ^b	0.03 (0.20)	0.007 ^b
	Male	31,459	1.75 (2.42)		0.06 (0.37)		0.04 (0.26)	
Birthplace	Israel	31,374	1.70 (2.38)	0.009 ^b	0.06 (0.36)	0.005 ^b	0.04 (0.26)	0.112 ^b
	Other	3076	1.81 (2.45)		0.07 (0.36)		0.04 (0.26)	
	[§] Total	34,450	1.72 (2.39)		0.06 (0.35)		0.04 (0.26)	

^a Kruskal-Wallis test.^b Mann-Whitney test.^a F= Subjects potentially exposed (+) or were not exposed (-) to water fluoridation.[#] R= Subjects affected (+) or not affected (-) by the dental care reforms.[§] Total may vary slightly in some categories due to missing values.**Table 3**

Association between ICS, SEC, BMI, age, and treatment needs.

	N	Number of teeth in need of restorations		Number of teeth in need of RCTs		Number of teeth in need of extractions	
		Correlation Coefficient	*P value	Correlation Coefficient	*P value	Correlation Coefficient	*P value
Intellectual Capability Score (ICS)	33,927	-0.15	<0.001	-0.11	<0.001	-0.11	<0.001
Socioeconomic cluster (SEC)	30,696	-0.14	<0.001	-0.09	<0.001	-0.08	<0.001
Body Mass Index (BMI)	34,428	0.00	0.557	-0.02	0.003	-0.01	0.184
Age	34,450	0.03	<0.001	0.02	0.001	0.02	0.001

* Spearman correlation test.

Table 4Generalized Linear Model for number of required restorations as the dependent variable ($P < 0.001$).

Variable	B	P value	Exp (B)	Lower 95% CI ^{&}	Upper 95% CI ^{&}
Intercept	1.03	0.004	2.80	1.38	5.68
Sex	Female	–	1.00	–	–
	Male	0.33	<0.001	1.39	1.26
Place of Birth	Israel	–	1.00	–	–
	Other	0.05	0.319	1.05	0.96
Socioeconomic cluster (SEC)	-0.15	<0.001	0.86	0.84	0.87
Intellectual Capability Score (ICS)	-0.02	<0.001	0.98	0.98	0.99
Age	0.11	<0.001	1.11	1.07	1.15
Study group	Group A (+ F ^a , + R [#])	–	1.00	–	–
	Group B (+ F ^a , - R [#])	-0.08	0.049	0.93	0.86
	Group C (- F ^a , - R [#])	0.43	<0.001	1.53	1.44
				1.63	

^a F= Subjects affected (+) or not affected (-) by water fluoridation.[#] R= Subjects affected (+) or not affected (-) by free dental care reforms.[&] CI, Confidence Interval.

fluoridation in 2002. Individuals born in 1994 were 8 years old or more at the time, and their permanent dentition had already fully developed in terms of enamel formation (not including 3rd molars). In contrast, subjects born in or after 1996 were at a critical age in teeth development (0–6 years of age), and they were profoundly affected both in terms of systemic fluoridation's affecting the developing enamel as well as in terms of oral fluoridation protecting the erupting permanent teeth.

Water fluoridation has proved to be both effective and widespread in helping to tackle dental health inequalities that arise from socioeconomic disparities [15–17]. In August 2014, the Israeli parliament revoked legislation that mandated water fluoridation. The main reason for this decision was attributed to the appointment of a new Minister of Health who held a strong anti-fluoridation opinion [18]. According to a

study conducted at a large national healthcare provider, this move was followed by an increase of approximately twofold in dental treatment needs after 6 years [18]. The harmful effect of fluoridation cessation was also demonstrated in China and several European countries [19]. There were smaller differences between the two younger age groups (i.e., those born between 1996 and 2000 vs. those born in and after 2001) in treatment needs even though the latter had enjoyed the nationwide reform of free dental care for children. This group even had slightly (but significant) higher restoration needs according to the GLM, although the significance can be attributed primarily to the large sample size rather than be considered a meaningful difference.

Some studies, such as the one carried out in 11 countries by Palencia et al., claim that public dental care coverage can lower the socioeconomic inequalities in the use of dental care services [20]. Others claim that free dental care does not change the overall caries experience (measured by DMFT- decayed, missing, filled teeth index), but rather changes the ratio between treated and untreated caries lesions [21]. In contrast, other authors believe that systems of oral health that focus on such clinical interventions and are increasingly technology-based do not contend with the underlying causes for caries and other oral diseases [10].

In Israel, 70% of the general provision of dental care for children is in public-funded clinics that provide cheaper dental treatments. That number is higher (up to 85%) in low SEC groups [22]. Another sign of socioeconomic inequality is the fact that children of lower SEC groups attend these dental clinics more for urgent treatments and less for routine checkups in comparison to children of higher SEC groups [22]. In that regard, according to a recent survey of 618 mothers, the free dental care reform in Israel did increase routine checkup attendance in the lower SEC population [23].

Our results showed that the free dental care reform did not have any significant positive impact on caries-related treatment needs in the study population. We suggest that several reasons can account for these findings. First, other factors, not measured in this study, may have impeded the improvement of dental health over the years, such as the continually growing sales of foods and beverages containing added

sugars and sweeteners [24]. Since markets in high SEC populations are near-saturated, many manufacturers of high sugar content foods and beverages are now targeting more low-income and middle-income populations [25]. A clearcut example of the negative impact of a significant increase in consumption of high content sugar products is the rapid rise of dental caries among the Ethiopian immigrants during the first years after their arrival to Israel and the subsequent change to a more cariogenic diet [26]. Second, it is possible that the price of dental treatment in the already subsidized national healthcare system in Israel wasn't the main reason for not attending dental appointments in the first place, and so the small and possibly negligible reduction in price for dental care was not effective in enhancing dental health [10]. Third, our study population is comprised of young army recruits, and therefore does not represent certain sectors that have low military recruitment rates, such as Arab Muslims and Orthodox Jews [7]. Those populations are considered to have large proportions of low SEC [7] and may therefore have gained more from the dental reform. Lastly, the dental reform was introduced in 2010 and included children up to the age of 10 years. It was gradually extended until it also covered adolescents <18 years of age by 2018. It is possible that insufficient time has passed to measure a significant change for the better.

The payment method used by public health providers in the Israeli dental health reform is primarily fee-for-service. This method has been criticized for potentially incentivizing overtreatment [10,27]. In contrast, alternative payment models like capitation may incentivize undertreatment [10,27]. Therefore, we cannot conclusively determine whether the quality of care in the reform was influenced by the payment method.

We performed an additional analysis (data not shown) in order to rule out the possibility that those in the lower SEC were actually affected by the reform in dental care provision but that this change was masked by the data from the higher SEC groups. We re-examined the association between the year of birth (i.e., the effect of fluoridation and the dental care reform) and dental treatment needs, but this time only in the lower SEC group (1–4). The results showed that overall treatment needs were higher in the lower SEC groups, but that the trends in differences between the study groups (A–C) remained the same, demonstrating that all SEC groups reacted similarly to the changes over the years. With respect to gender differences, it's worth noting that our study population comprises mostly combat soldiers, resulting in a relatively low proportion of women. Therefore, it may not be representative of the general population, and we cannot draw any conclusions regarding gender differences based on these findings in this population.

Our results indicated that BMI was not significantly associated with higher treatment needs. We believe this may be due to the fact that the majority of our subjects had a healthy weight or were slightly outside of the healthy range, and thus our results suggest BMI was not a significant factor in determining oral health.

This reform exemplifies the interventionist approach to healthcare by providing better access to dental treatments. However, a significant disadvantage is that it may not address the underlying problems, such as an unhealthy diet and tobacco and alcohol use that are common to many non-communicable diseases, including heart disease, stroke, cancer, and diabetes. [28]. Health programs aimed at reducing these common risk factors are difficult to implement and also very hard to measure in terms of impact and health improvement [9]. Improving the treatment of these common risk factors requires integration of the dental health system with the general one [10]. Legislation that targets these issues was recently passed in Israel; Mandatory marking of products with high content of sugar and/or sodium was implemented in January 2020, and a report of the Ministry of Finance in August 2022 claims that the sales of these products are gradually decreasing. Additionally, a new tax on beverages with high sugar content was introduced at the beginning of 2022 [29], although its fate is unknown [30]. Similar marking of food products has existed in Britain for many years (voluntary, since 2006) and Latin America (gradually since 2016).

Taken together, our findings reveal conflicting factors on the oral health of low SEC populations in Israel. On one hand, dental care is now free for children/adolescents and the benefits of several years of water fluoridation are well-documented. On the other hand, there is still a rise in products containing high levels of sugar, and harmful effects due to the 2014 cessation of water fluoridation can be anticipated.

The major limitations and shortcomings of our study are that the study population was comprised essentially of healthy young adults which may not reflect the general population. Additionally, we did not collect data on smoking, alcohol abuse, or other unhealthy habits that are linked to dental health issues. However, this information may be available in other published studies [31]. One other limitation of this study is the involvement of a significant number of dentists in performing the dental examinations. However, these dentists have comparable years of experience, they are supervised by a more experienced regional chief dental surgeon and undergo the same military dental training. Furthermore, the dental services provided by the IDF military are not financially based on a fee-for-service model. Instead, all dental plans are solely based on medical necessity, promoting a consistent clinical approach. While there may be some variability in caries diagnoses, any potential bias is non-differential due to the aforementioned factors. In this article, we focused on the dental effects of water fluoridation, while legal and ethical aspects are addressed elsewhere [2]. Further research is required to explore the nature of the potential associations suggested in this study, including study designs with temporal relations, to address the question of the causality.

5. Conclusion

Our study found that mandatory water fluoridation was significantly associated with a decrease in the need for caries-related treatment. In contrast, national dental health legislation providing free dental care to children and adolescents did not show a significant association with such a decrease. Therefore, we suggest that water fluoridation should be continued to maintain the observed reduction in treatment needs.

Author contributions

Dan Henry Levy: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing - original draft. **Harold Sgan-Cohen:** Supervision, Validation, Writing - original draft. **Michael Solomonov:** Software, Methodology, Writing - review & editing. **Avi Shemesh:** Project administration, Supervision, Writing - review & editing. **Eran Ziv:** Data curation, Formal analysis, Investigation. **Elon Glassberg:** Project administration, Supervision, Writing - review & editing. **Nirit Yavnai:** Conceptualization, Data curation, Formal analysis, Statistical analysis, Investigation, Methodology, Software, Visualization, Writing - review & editing.

Declaration of Competing Interest

All authors declare that they have no conflicts of interest.

Acknowledgments

The authors received no financial support and declare no potential conflicts of interest with respect to the authorship and/or publication of this article. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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