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ORIGINAL RESEARCH

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The effect of cessation of community water fluoridation on dental caries among children aged 5–6: a cross-sectional study

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Abstract

Background: Community Water Fluoridation (CWF) was implemented in Israel from 1981 to 2014. Following the discontinuation of fluoridation, there has been a debate about changes in the prevalence of of caries and dental treatments in Israel. This study aims to illustrate the effects of halting fluoridation on 5–6-year-old children, especially those from low socio-economic backgrounds. **Methods**: This cross-sectional study used data from the Maccabi-Dent database, covering the period from 2014 to 2019 for children aged 5 to 6. The dataset comprised 539,661 treatments. We compared the frequency of treatments carried out in 2014–2015, when fluoride was still active, with those conducted in 2016–2019, when the influence of CWF was no longer present. Statistical tests including Levene's, analysis of variance (ANOVA), and *post-hoc* Games-Howell tests were conducted. **Results**: The frequency of dental treatments increased between 2014–2019 among children aged 5–6. When comparing the frequency of treatments with and without CWF, the number of restorations increased from 54,101 to 135,539, along with a 22% increase in dental checkups. There were significantly fewer treatments performed before the cessation of fluoridation (2014–2015) than after the cessation (2016–2019). Children from lower socioeconomic backgrounds underwent more dental treatments. **Conclusions**: This study indicates that Community Water Fluoridation reduces the incidence of dental caries, particularly evident in the significantly higher number of treatments among those from lower socioeconomic backgrounds.

Keywords

Community water fluoridation; Public health; Dental caries; Socioeconomic; Fluoride

1. Introduction

Dental caries is the most common chronic infectious oral disease among children and adolescents [1]. This disease is caused by a long-term imbalance of factors in the mouth, such as the presence of specific bacteria, which can be disrupted by factors like sugar intake and dental biofilm. This imbalance can lead to tooth demineralization and the development of carious lesion [2]. Keeping good oral hygiene, controlling fluoride exposure, and maintaining a diet low in fermentable carbohydrates are effective strategies for preventing and managing dental caries [3].

The prevalence of dental caries varies across different population groups. Research has shown that caries are more prevalent in lower or middle-income groups and linked to socioeconomic status [4]. In cities with higher incomes, oral health expenditures are mostly for prevention, while in lower or middle-income groups, expenses are mostly for pain relief and emergency treatments [5].

Fluoride is a naturally occurring anion and the fluoride content in rivers, streams, and wells usually remain below 0.5 mg/L, although in certain areas, it may range from 0.5–1.5 parts per million (PPM) [6]. The fluoride ion exhibits a strong affinity for biological apatite, a key component of tooth enamel. It readily replaces the hydroxyl component of the calcium hydroxyapatite with fluoride, transforming it into fluorapatite. This altered structure is more robust and less susceptible to the formation of initial carious lesion in the enamel [7]. Apart from fortifying the tooth structure, fluoride also hinders glycolysis in cariogenic bacteria, thus impeding the production of acid that damages teeth. Furthermore, at elevated levels, fluoride demonstrates bactericidal properties [8]. The recommended fluoride concentration in drinking water falls within the range of 0.7–1.2 PPM [6].

The application of fluoride can be done through various methods. The most common method is the daily use of fluoride-containing toothpaste or gel. Another method is through professional topical applications by dentists or hygienists who use highly concentrated fluoride-containing varnishes. Entire communities can be exposed to fluoride

through water, milk and salt fluoridation. Community Water Fluoridation (CWF) offers several advantages, including topical exposure throughout the day, reaching the entire population regardless of socioeconomic status, and a low cost benefit ratio [9, 10].

Tobias *et al.* [11] examined the effectiveness of water fluoridation and the impact of its cessation by studying the number of dental treatments in children aged 3–12 years from areas where water fluoridation was stopped and those that never had optimal fluoride levels in water in Israel. They found that between 2014–2015, there was no significant change in the number of dental treatments between cities. However, between 2016 and 2019, when the effects of fluoridation cessation could play a role, the number of dental treatments increased with age, almost doubling [11]. Similarly, Zusman *et al.* [12], found that the DMFT (Decayed, Missing and Filled Teeth) among 12-year-olds residing in cities with water fluoridation was 1.39, compared to 1.83 in unfluoridated areas.

In recognition of the role of fluoride exposure in preventing dental caries, legislation for water fluoridation in Israel was passed in 2001. By 2002, fluoridation became mandatory, with 75% of the population consuming fluoridated water and a plan to reach 85% consumption [13]. Before fluoridation Israel suffered from caries rates of 90% among children, and public dental services were very limited, highlighting the need for fluoridation legislation. However, in 2014, the law was repealed, and fluoridation discontinued. Concurrently, drinking water began to be supplied from desalination plants with 0 mg/L fluoride, (less than the natural concentration of fluoride) [14].

To reduce the high rate of tooth decay, community dental care was expanded. In 2010, the "Dental Health Services for Children in the National Health Insurance Law" was established, which outlined the services and eligibility for dental treatments for children under the age of 8. Free or low-cost routine check-ups and preventive treatments were made available through the health funds [15]. A study conducted in 2014 by Shahrabani *et al.* [16] demonstrated that access to routine examinations and treatments significantly increased after the reform, particularly among disadvantaged populations. This reform helped bridge societal gaps and enhance dental health. In 2019, the dental reform was extended to cover individuals up to the age of 18 and the elderly [17].

All citizens in Israel are associated with a specific health fund and receive health services through it. The largest fund is "Clalit", followed by "Maccabi", which has 2.6 million members. Approximately 50% of dental treatments can be accessed through the health fund, with the government sharing the treatment costs. "Maccabi-Dent" operates 59 clinics, employs 1400 dentists, and caters to a diverse population. The research used data from the records of Maccabi-Dent patients from various socioeconomic backgrounds, making the extensive database a reliable tool for evaluating the entire population [12].

The research aims to: (1) Investigate the impact of discontinuing water fluoridation on the number of dental treatments. (2) Explore the influence of socioeconomic status on the frequency of treatments.

We hypothesize that in the absence of fluoridation, there will be an increase in the number of treatments across all age groups, particularly in vulnerable populations.

2. Materials and methods

The study was approved by the Institutional Review Board (IRB) MHS 0157-20 and the Helsinki committee of Maccabi Healthcare services. Data for this Cross sectional-based records study was collected from the computerized records of "Maccabi-Dent" for 5–6 years old treated between 2014 and 2022. The treatments included extractions, root canal treatments, crowns and restorations. Treatments included extractions, root canal treatments, crowns and restorations, which were recorded as treatment codes and examined for relevance to the study.

Calculation of frequency of treatment: We compared the frequency of treatments conducted when fluoride in the drinking water could have an effect (2014–2015) with the frequency of treatments in the years without the impact of CWF (2016–2019). We also assessed the role of socioeconomic status, gender and the type of treatment administered in the total number of treatments.

Treatment frequency was calculated as the total number of a particular treatment performed in each clinic per year divided by the number of examinations performed in the same clinic in the same year. Socioeconomic levels were analyzed based on a 9-point scale, where a score of 9 indicates high socioeconomic status, and 1 indicates the opposite. Data was analyzed using Python 3.11.5 software, with significance set at $p < 0.05$. A Levene's test for the equality of variances was performed to assess the homogeneity of the variables. Depending on its outcome, ANOVA tests were used to examine the significance of the effects among the variables. Additionally, we used *Post-hoc* Games-Howell tests (occasionally with Bonferroni corrections) to compare group means and explain which group means are significantly different from other group means. Finally, we used Linear regression models to analyze the correlation between socioeconomic status and each treatment type.

3. Results

Between 2014 and 2022, 539,661 treatments were performed for children aged 5–6. Table 1 illustrates the number of checkups, restorations, root canals, extractions and crowns performed each year. Notably, there were more treatments per year from 2016 to 2019 compared to 2014–2015, particularly in the categories of restorations and crowns. Specifically, crown placements increased significantly from 14,380 in 2014–2015 to 43,987 in 2016–2019. Similarly, restorations increased from 54,101 to 135,539 during the same period. Meanwhile, the number of checkups showed a more modest growth of 22% between the two-time frames.

Analytic data: From 2014 to 2022 (as shown in Fig. 1), there were four times more restorative treatments than root canal treatments (297,296 restorations versus 105,815 crowns and 76,347 root canal treatments). Furthermore, the total number of treatments increased until 2020, when the COVID-19 pandemic began, and then the increase stabilized (f =

TABLE 1. Number of treatments by year.

Year	Checkups	Restoration	Root canal	Crowns	Extractions	Total
2014	33,869	27,104	6308	7086	6062	46,560
2015	33,534	26,997	6423	7294	5626	46,340
2016	36,890	31,145	7489	9130	6346	54,110
2017	37,026	33,631	7712	9747	6406	57,496
2018	37,828	35,208	8577	11,388	6850	62,023
2019	38,372	35,555	9300	13,722	7158	65,735
2020	33,169	33,617	9246	14,112	6800	63,775
2021	37,082	36,521	10,193	15,957	7169	69,840
2022	39,624	37,518	11,099	17,379	7786	73,782
Total	327,394	297,296	76,347	105,815	60,203	539,661

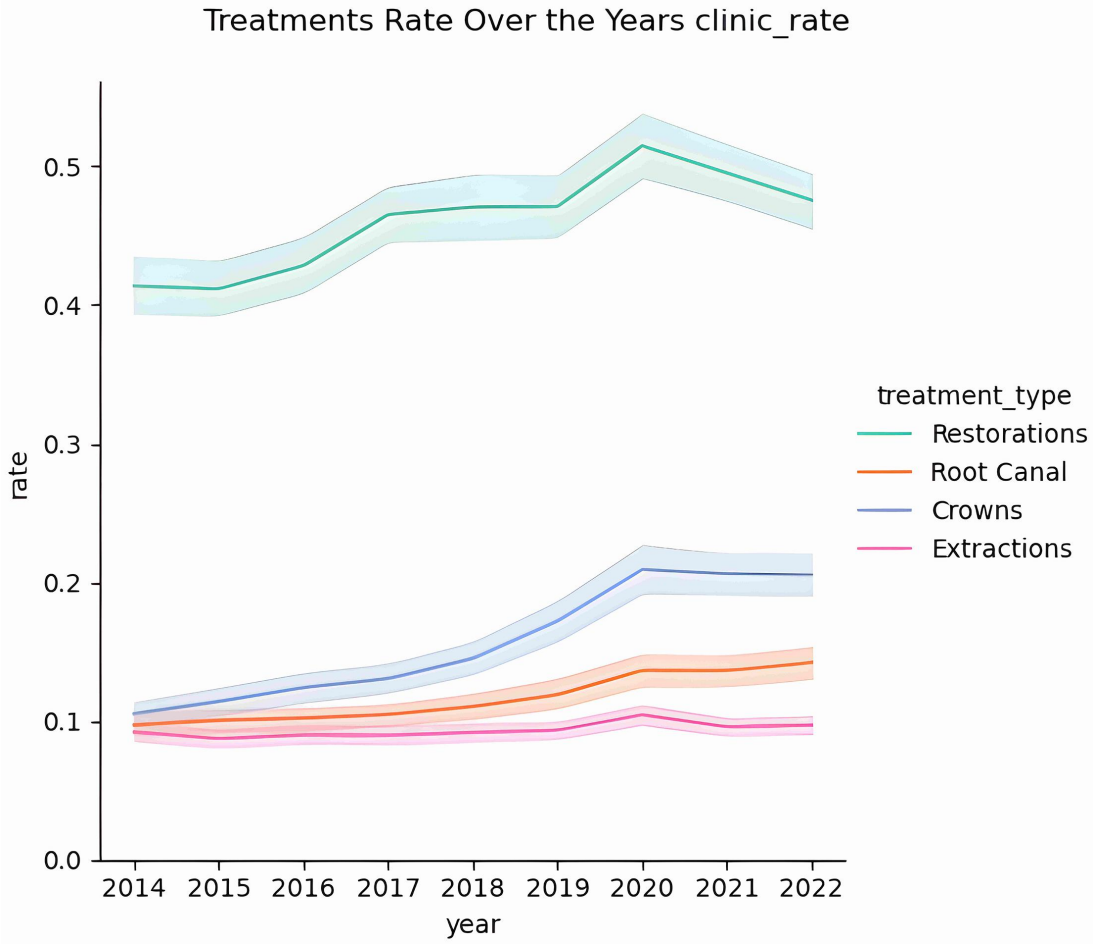

FIGURE 1. Mean treatments 2014–2022.

641.11, $p < 0.05$).

In Fig. 2 each column represents a different socioeconomic group and the different types of treatments are shown along the x-axis. Patients from a low socioeconomic status had the highest frequency of restorative treatments (>1.0), while those from mid and high socioeconomic levels had frequencies of approximately 0.8 and 0.6 respectively (f = 641.11, $p <$ 0.05). Crown placements showed a similar pattern, with lower socioeconomic status correlating with a greater number of dental treatments, except for extractions, where the difference between the groups was not statistically significant.

Fig. 3 indicates that the frequency of restorations, crowns and root canal treatments increased following CWF cessation (f = 176.19, $p < 0.05$).

Fig. 4 shows that as the socioeconomic status decreases, more dental treatments are performed. This negative correlation was high for restorations, root canal treatments and crowns ((r = 0.675), (r = 0.582) and (r = 0.571) respectively), and was lower regarding extractions (r = 0.281). treatments between the low and middle classes, whereas, in the absence of fluoridation, there is a significant difference between these classes ($p < 0.05$).

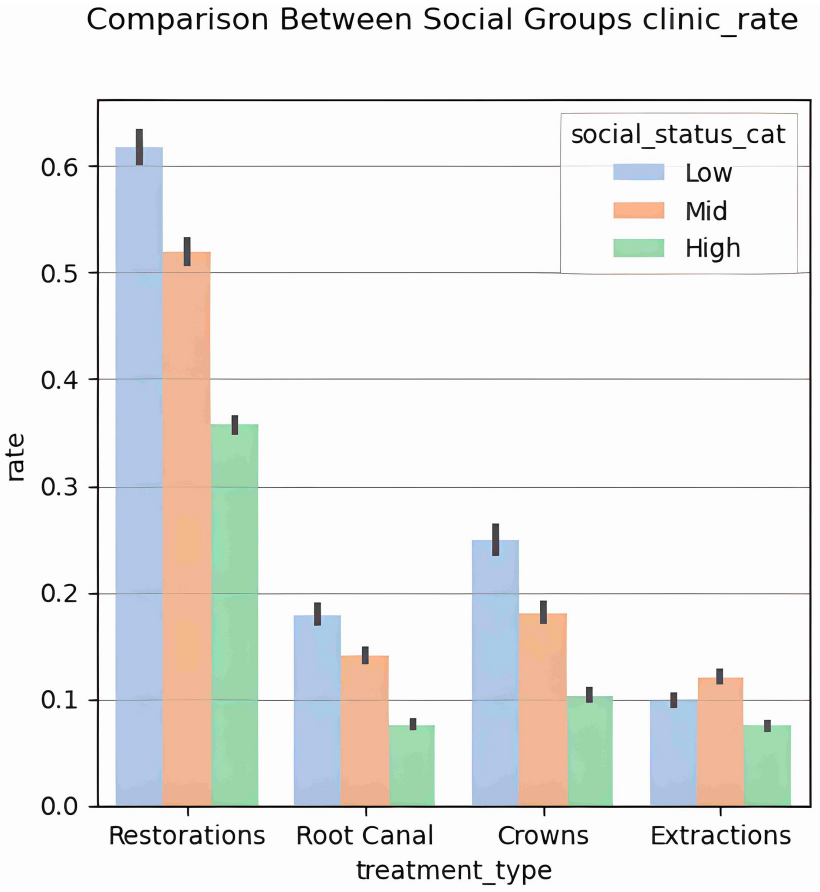

FIGURE 2. Socioeconomic status and treatments.

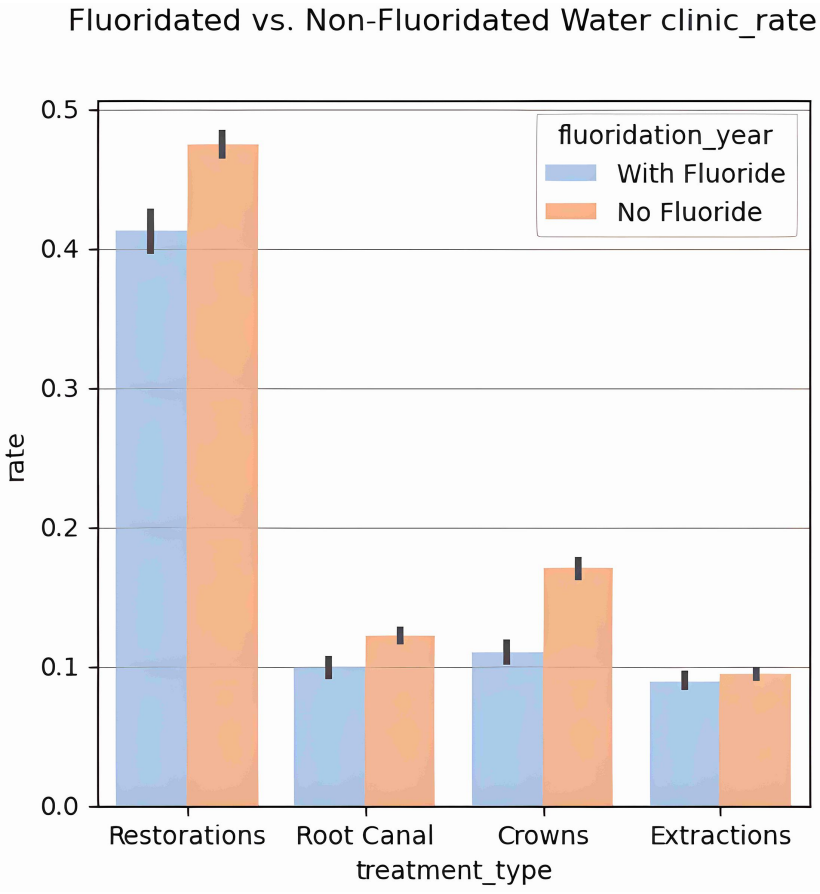

FIGURE 3. Mean of treatments by treatment type.

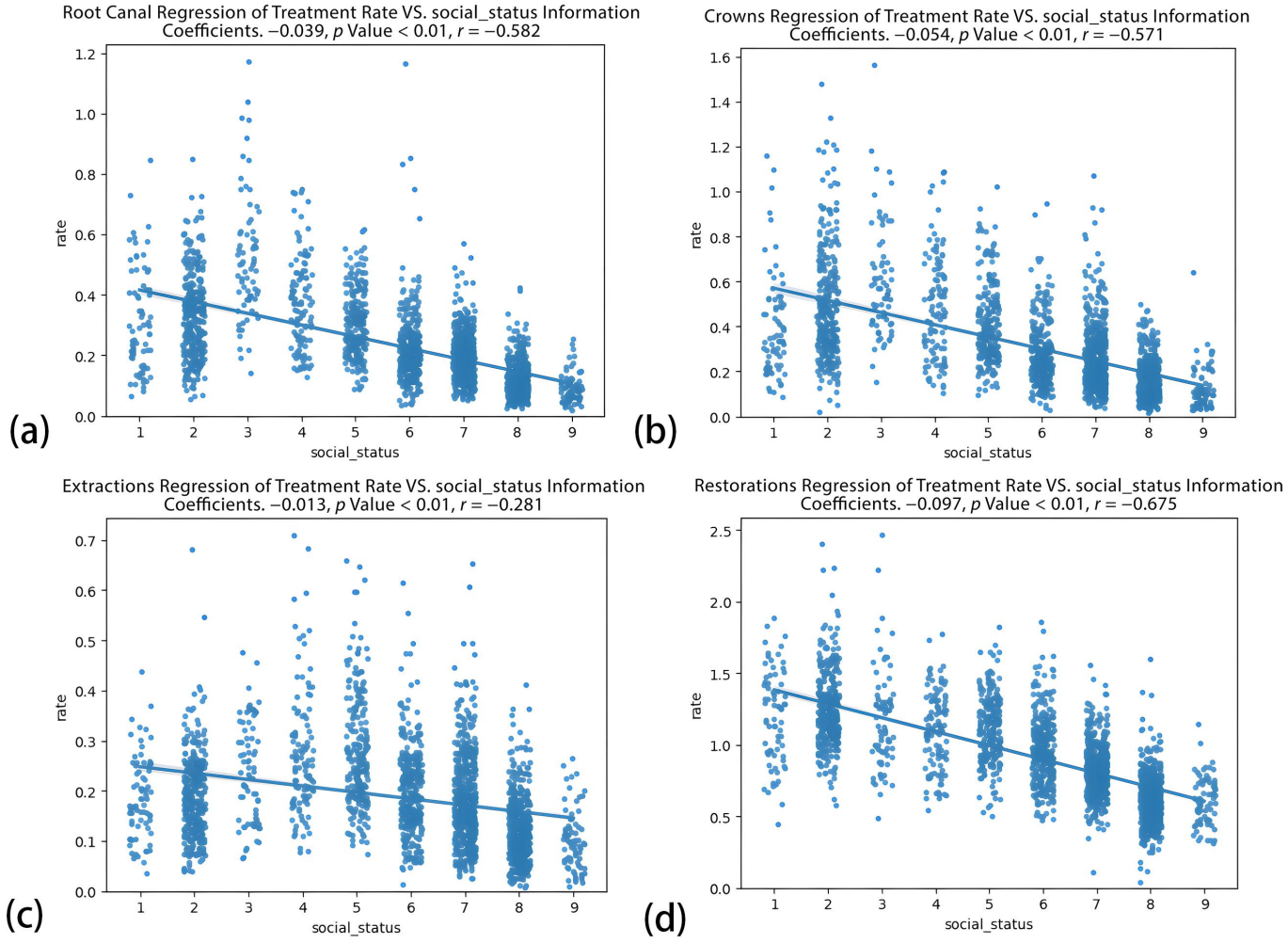

FIGURE 4. Correlation between Socioeconomic Status and the Rate of Different Dental Treatments. (a) Root Canal Treatments, (b) Crowns, (c) Extractions, (d) Restorations.

Fig. 5 illustrates the relationship between socioeconomic status, CWF, and the frequency of dental treatments in Israeli children aged 5–6. In the presence of fluoridation, there is no significant difference in the rate of treatments between the low and middle classes, whereas, in the absence of fluoridation, there is a significant difference between these classes ($p < 0.05$).

4. Discussion

The State of Israel had community water fluoridation (CWF) for a long time to reduce dental cavities in the population [18]. However, CWF was stopped in 2014, reducing fluoride exposure, especially for socioeconomically disadvantaged groups. Our study aimed to see how stopping fluoridation in Israel affected the dental health of 5–6-year-old children from different backgrounds.

Using data from Maccabi-Dent, we looked at how often 5–6-year-old needed dental treatment and how stopping fluoridation affected dental treatment rates in Israel. We discovered a strong link between stopping CWF and more dental treatments. In 2014–2015, when there was still fluoride in the water, the average number of treatments was much lower than in 2016–2022, when fluoride was no longer in the water supply.

Another study in Israel in 2022 (Tobias *et al.* [11]) also looked at the effects of stopping fluoridation between 2014 and 2019. Tobias *et al.* [11] studied clinics in different areas, where fluoridation was stopped, somewhere it never existed, and somewhere it was not significantly implemented. They confirmed a large increase in dental treatments from 2016 to 2019. The number of treatments almost doubled after fluoridation stopped, compared to when it was in effect from 2014 to 2015 [11].

Our findings are supported by research from around the world. A Canadian study compared the risk of cavities in 7–8-year-old children from two different cities: Calgary, where fluoridation was stopped in 2011, and Edmonton, where fluoridation continued. The study showed that children not exposed to fluoridated water had a higher risk of dental cavities in their baby teeth compared to children exposed to fluoride [19]. Similarly, a study on the dental health of a group of 0–18-year-olds compared treatments during the peak years of fluoridation (2003) with the period after fluoridation stopped (2012) and revealed a significant increase in dental treatments after fluoridation ceased [20].

The correlation between socioeconomic status and the prevalence of dental caries that we found is congruent with the findings of other studies. For example, a 2019 study in

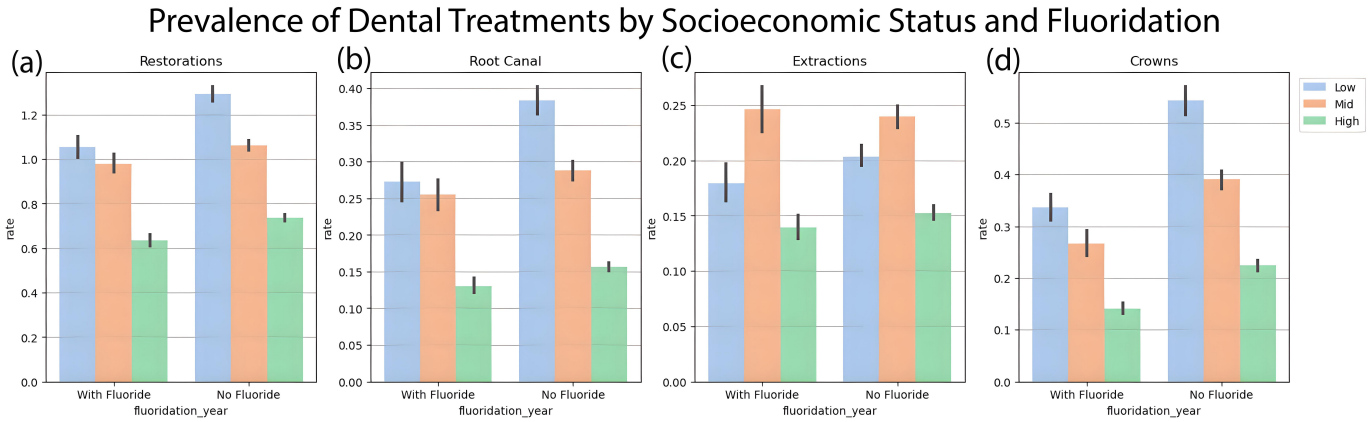

FIGURE 5. Prevalence of Dental Treatments by Socioeconomic Status and Fluoridation. (a) Restorations, (b) Root Canal Treatments, (c) Extractions, (d) Crowns.

Egypt (Abbass MMS *et al.* [21]) showed that children aged 5–6 from lower socioeconomic backgrounds experienced significantly higher rates of dental cavities than those from higher socioeconomic backgrounds. Similarly, in a group of 40,360 children aged 3–5, Zhang *et al.* [22], found that the DMFT (Decayed, Missing and Filled Teeth) index was lower when the parents belonged to a more established and educated demographic.

Likewise, Lennon *et al.* [23] found that when comparing children from high and low socioeconomic backgrounds living in non-fluoridated areas, the DMFT index was 1.52 for children from a low socioeconomic status, compared to 1.20 in the children from a high socioeconomic status living in the same non-fluoridated area. The gap between the classes narrowed in areas with fluoridation; the DMFT index in the population from the lower strata was 1.01 compared to 0.97 in the established population [23]. Kim *et al.* [24], found fewer cavities among children residing in fluoridated areas and they also showed that there was no difference in the prevalence of dental cavities across different societal strata in the fluoridated areas.

The absence of statistically significant findings regarding the correlation between the frequency of dental extractions and the discontinuation of fluoridation or socioeconomic variables necessitates a thorough evaluation.

Moreover, the research indicates that from 2019–2022, the rate of dental procedures decelerated even in the absence of fluoride in the water supply. However, it is plausible to presume that during this period, the emergence of the COVID-19 pandemic in Israel impacted patients' willingness to attend dental appointments and treatments. This hypothesis is supported by a study conducted by Üstün *et al.* [25] in 2021, which examined the records of 1454 patients. The results demonstrated a 50% decrease in emergency dental treatments during the pandemic, alongside a corresponding reduction in overall dental procedure frequency. Additional studies further substantiate this hypothesis; for instance, Choi *et al.* [26] observed a decline in dental care utilization in the United States during the COVID-19 pandemic, which also affected medical visits, albeit to a lesser extent. Similarly, Akbari *et al.* [27] reported a significant decrease in treatment volume in Iran, with 39.44% fewer services provided per day. In Taiwan, Lee *et al.* [28] found reductions in both medical and dental visits across hospitals and clinics during the COVID-19 period. Furthermore, a study from Germany conducted by Schwendicke *et al.* [29] revealed a 76% decrease in the ratio of periodontal treatments performed by dentists during the pandemic.

Although the study primarily examines the impact of discontinuing community water fluoridation, other potential factors such as oral hygiene, dietary habits and more may also exert influence on dental health and treatment outcomes.

5. Limitations

The data used in our analysis did not include the diagnosis of specific conditions. We assumed that all treatments were intended to address dental caries, but this may not be universally applicable. The data presented in this study covers the years 2014–2022, but we only analyzed data between 2014–2019 due to a potential bias related to the COVID-19 pandemic, which began in Israel in 2020. The method used to define the "frequency of treatments" by dividing the number of specific treatments by the number of checkups might not fully capture the impact of CWF cessation on dental health. This standardization assumes that the number of checkups is a stable and unbiased denominator, which might not account for variations in access to dental care or changes in healthcare-seeking behavior over time. Another limitation is related to the chosen age group, which is close to the period in which tooth replacements are, on average, frequent. This can contribute to an assessment of the need for treatment impacted by the proximity of tooth exfoliation, in addition to modifying the sample in a heterogeneous way.

6. Conclusions

This study confirms that community water fluoridation (CWF) significantly reduces the incidence of dental caries among children, with a particularly notable impact on narrowing socioeconomic disparities. Following the cessation of CWF in Israel, there was a clear rise in dental treatments, especially among children from lower socioeconomic backgrounds, high-

lighting fluoride's crucial role in promoting oral health equity. These findings underscore the importance of maintaining public health interventions like CWF to ensure better dental outcomes across all population groups.

AVAILABILITY OF DATA AND MATERIALS

The supporting data for this study is held by "Maccabi-Dent" and is subject to access restrictions. These data were utilized under specific licensing conditions for this research and are not openly accessible. However, the data can be provided by the authors upon a reasonable request and with the necessary authorization from "Maccabi-Dent".

AUTHOR CONTRIBUTIONS

TG, ACL, MJ—conception and design of the study, analysis of the data, writing, reviewing, and editing. FM—conception and design of the study, data curation. CT—supervision and methodology. HD—conception and design of the study, data curation. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The present study was approved by the Institutional Review Board (IRB) MHS-0157-20 of the Helsinki committee of Maccabi Healthcare Services due to the retrospective nature of the study. As the study is based on retrospective data and does not involve direct patient contact, written informed consent was waived by the Institutional Review Board (IRB) MHS-0157-20 of the Helsinki Committee of Maccabi Healthcare Services.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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