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Worldwide interest in silver diamine fluoride over the last decade: A longitudinal retrospective study

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Original Article

Abstract

BACKGROUND AND AIM: Silver fluoride solutions have been used successfully over the past 40 years for the prevention and inhibition of dental caries, in both clinical and in vitro studies. This study was performed to investigate worldwide interest in silver diamine fluoride (SDF) over the last decade using Google Trends.

METHODS: On January 6, 2020, the term 'silver diamine fluoride' was searched for on Google Trends and the relative search volume (RSV) was downloaded. This search was first performed worldwide, and then within the five most-searched countries, i.e., the United States of America (USA), Canada, Egypt, India, and the United Kingdom (UK), from January 2010 to December 2019. Data were subjected to multiple time-series analysis and Kruskal-Wallis test, and autoregressive integrated moving average (ARIMA) forecasting models were generated.

RESULTS: The highest RSVs were obtained in the USA (100) and Canada (99). The monthly RSV values were significantly different among countries ($P < 0.001$). Multiple time-series analysis showed a marked increase in the number of searches including the term 'silver diamine fluoride' since 2014.

CONCLUSION: There has been an increase in interest regarding SDF among Google users over the last decade. The increase started in 2014, with the highest number of searches for this term being conducted in the USA and Canada.

KEYWORDS: Silver Diamine Fluoride; Dental Caries; Trends

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Tooth decays are natural processes, in which bacteria in the biofilm cause fluctuations of pH that can lead to erosion of dental hard tissues, in turn resulting in visible lesions. Tooth decays are the most prevalent childhood disease worldwide.[1]

Traditional treatment of the developing lesions requires removal of caries and placement of a restoration. Restoration longevity depends upon the seal and size used to isolate any remaining caries. However, the lesions can be remineralized through early detection.[2]

Silver diamine fluoride (SDF) has been used worldwide since the early 1970s at a concentration of 38% (44800 ppm fluoride), to prevent caries lesions via its cariostatic properties.[2,3] In 2014, SDF was approved by the United States Food and Drug Administration (USFDA) as a desensitising agent, but many practitioners have been using SDF off-label to treat and prevent caries.[4] SDF has been used for decades to help manage dental caries in several countries, and became available in the United States of America (USA) in March 2015.[5] In 2017, a guideline was published entitled the 'Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those with Special Health Care Needs' by the American Academy of Pediatric Dentistry (AAPD).[6] Use of SDF has spread rapidly in the Third World and underserved populations due to its ease of application, low cost per

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application, and few side effects.[2]

For caries management therapy, SDF is used off-label, similar to fluoride varnish.[7] SDF represents a novel active chemotherapeutic agent that can attenuate the progression of caries lesions and aid in the management thereof.[5] When applied to the tooth, the surface reacts with hydroxyapatite forming calcium fluoride, silver phosphate and precipitated protein silver.[8,9]

The use of SDF has recently attracted interest due to its successfulness in preventing caries.[10] Clinical trials of SDF showed favourable results in preventing caries of preschool children.[11,12] Systematic reviews concluded that the application of SDF could be a preferable option for control of caries progression in preschool children, especially those with restricted access to dental care.[13,14]

However, SDF use also has unique consequences that hamper its broader acceptance, i.e., staining of the teeth, which leads to low parental acceptance of aesthetic outcomes following treatment. Off-label use, training, difficulty in procuring the product, and high cost represent additional barriers to the use of SDF in dental treatment.[14,15]

With continuously increasing Internet coverage worldwide, the use of search traffic data, social media data, and data from other web-based sources and tools may assist in the analysis of web-based behaviour and behavioural changes.[16] The most popular tool for analysing behaviour according to web-based data is Google Trends, which is a reliable tool for predicting changes in human behaviour; with careful selection of search terms, Google data can be used to accurately measure public interest in various topics.[17,18]

This study was performed to investigate changes in the worldwide interest in SDF over the last decade using Google Trends.

Methods

This infodemiological research was performed in accordance with the principles of the Declaration of Helsinki and Google's policies. Ethics committee approval was not necessary because this study used publicly available data with no personally identifiable information, and did not involve human subjects.[19-21]

Study design: Using the online tool of Google Trends, this longitudinal retrospective infodemiological study analysed the interest in SDF in different countries between January 2010 and December 2019, through analysis of structured computational data. Search strategies were devised in five distinct languages (English, Chinese, Italian, Portuguese, and French), covering all countries with sufficient relative search volume (RSV) data. There were insufficient RSV data for all languages except English. Therefore, the search was conducted only in English using the query term 'silver diamine fluoride'. Trends, including seasonality, in the obtained RSV data were analysed quantitatively and qualitatively.

Search volume trends: The Google Trends data used in this study comprised a random sample of "real-time" (last 7 days) and "non-real time" (from 2004 to 36 hours prior to the search) Google search queries.[22] Google Trends can analyse some proportion of the Google searches conducted for a given keyword, according to a particular geographical location and time frame. The RSV, or Google Trends Index, is then calculated for the keyword of interest, and ranges from 0 to 100.[23] A value of 50 indicates that the term is half as popular as it was at the peak of its popularity. Similarly, a score of 0 means that the term is less than 1% as popular as it was at its peak. These data can be downloaded in comma-separated value (CSV) format for further analysis and interpretation.[22]

On January 6, 2020, Google Trends was searched using the query term 'silver diamine fluoride' and the RSV data were downloaded. This term was searched for worldwide, and then within the five countries with the highest search volumes, i.e., the USA, Canada, Egypt, India, and the United Kingdom (UK), from January 2010 to December 2019; the 'all

categories and sources' criterion was selected. Data were downloaded as CSV files from the Google Trends website (https://trends.google.com/trends/), and were available in a monthly format.

Data were analysed using SPSS software (version 23, IBM Corporation, Armonk, NY, USA) based on a methodology described previously.[19,21] Mean, standard deviation (SD), median, minimum-maximum, and percentage values were calculated for descriptive statistics. The normality of the data distribution was tested using histograms and the Kolmogorov-Smirnov test. As the data were not normally distributed, the Kruskal-Wallis test was used for between-group comparisons. Autocorrelation (ACF) and partial autocorrelation (PACF) plots were used to evaluate trends in the time series data for each country. In addition, the curves derived from autoregressive integrated moving average (ARIMA) models were analysed heuristically to understand the variations therein over time. ARIMA models were developed to establish 12-month forecasts for SDF-related RSVs. The best-fitted models were those with the lowest normalised Bayesian information criterion (BIC) values. In all analyses, $P < 0.05$ was taken to indicate statistical significance.

Results

The term 'silver diamine fluoride' was searched for in five languages on Google Trends, but sufficient data were obtained only in English. The search was performed worldwide in all categories between January 1, 2010, and December 31, 2019, in English, and the highest RSVs were obtained for the USA (100) and Canada (99), followed by Egypt (29), India (22), and the UK (8) (Figure 1).

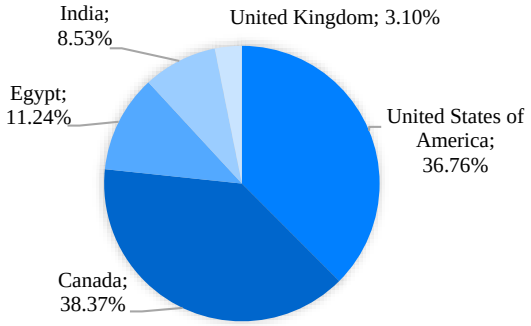

Figure 1. The relative search volumes (RSVs) for silver diamine fluoride (SDF) for the various countries included in this study

There were significant differences in monthly RSV among countries ($P < 0.001$). The median RSV of the USA was 2, while the other countries all had a value of 0. A value of zero does not indicate that no searches were done, but rather that less than 1% of the monthly search value (RSV = 100) corresponded to that country. Over the last decade, significantly more searches for the term 'silver diamine fluoride' were performed in the USA and Canada than in the other countries included in this study ($P < 0.010$); there was no significant difference among these other countries ($P > 0.050$). Mean, median, and minimum-maximum values of RSV data, as well as significant differences among countries, are shown in table 1.

Worldwide and individual countries searches for SDF showed an increasing trend from 2014 (Figures 2-4).

Table 1. Between-country comparisons of monthly relative search volume (RSV) values

Country	N	Mean ± SD	Median (minimum-maximum)	Test statistics	P
USA	120	9.14 ± 11.27	2 (0-34)[a]	$\chi^2 = 70.74$	< 0.001
Canada	120	9.96 ± 13.81	0* (0-45)[a and b]		
Egypt	120	5.77 ± 16.37	0* (0-100)[c]		
India	120	1.98 ± 2.60	0* (0-12)[b and c]		
UK	120	1.54 ± 2.65	0* (0-14)[c]		

[a-c]There is no difference between countries with the same letter; χ^2: Kruskal-Wallis test statistics; *The value of zero does not indicate that no searches were done, but rather that less than 1% of the monthly search value [relative search volume (RSV) = 100] corresponded to that country
SD: Standard deviation; USA: United States of America; UK: United Kingdom

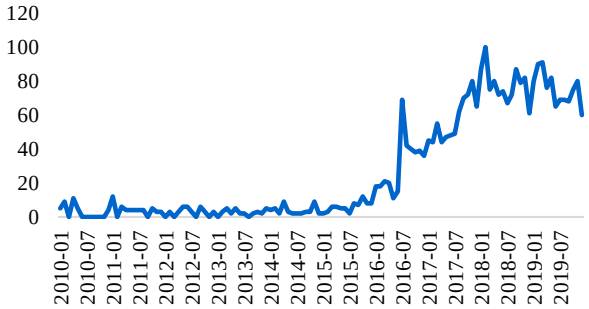

Figure 2. Multiple time-series analysis of web searches performed worldwide for silver diamine fluoride (SDF)

Seasonality analysis indicated an increase in the number of searches made in October over the last 10 years (Figure 5).

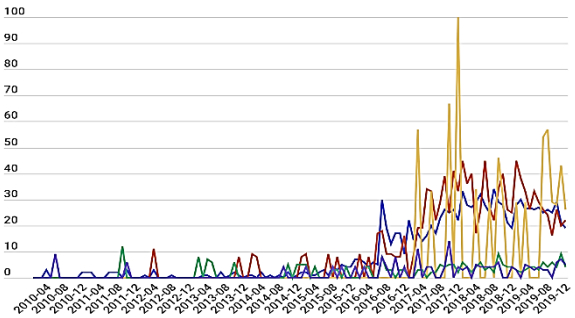

Figure 3. Multiple time-series analysis of the countries in which silver diamine fluoride (SDF) was searched for most frequently [blue: The United States of America (USA), red: Canada, yellow: Egypt, green: India, purple: The United Kingdom (UK)]

Figure 6 shows predictive (ARIMA) models of the interest in SDF shown by Google users.

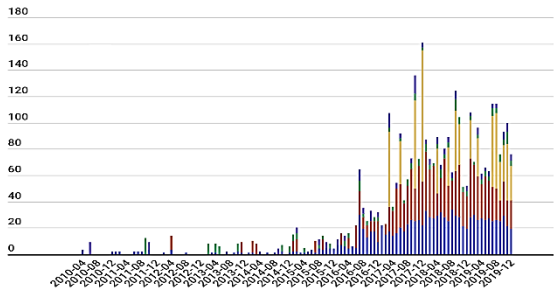

Figure 4. The cumulative relative search volumes (RSVs) for silver diamine fluoride (SDF) for the various countries included in this study [blue: The United States of America (USA), red: Canada, yellow: Egypt, green: India, purple: The United Kingdom (UK)]

The models showed normalised BIC values varying from 1.76 to 5.34. The curves derived from this analysis permitted the observation of trends in the data.

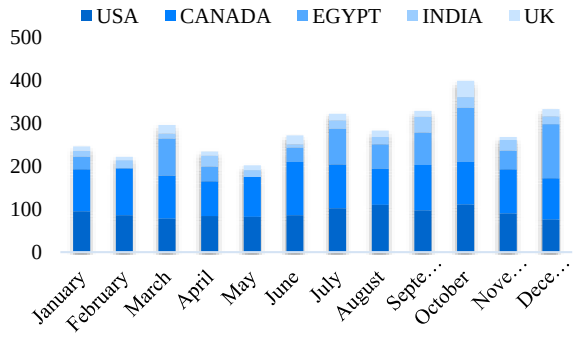

Figure 5. Distribution of searches by month and country [blue: The United States of America (USA), red: Canada, yellow: Egypt, green: India, purple: The United Kingdom (UK)]

The SDF-related RSV trends were similar between the last 6 months and the last 12 months in the USA, Canada, and India.

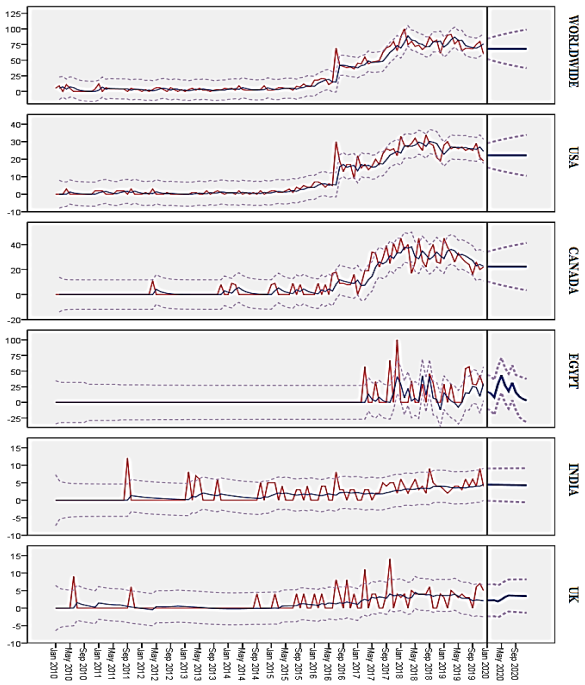

Figure 6. Chart showing trends in interest levels in silver diamine fluoride (SDF) among Google users, worldwide and separately for the United States of America (USA), Canada, Egypt, India, and the United Kingdom (UK); observed values (red lines), fit and forecast values (thin and thick blue lines, respectively), and upper and lower confidence limits (violet lines) are shown

Table 2. Autoregressive integrated moving average (ARIMA) model fit statistics

Country	ARIMA model	Normalized BIC	Ljung-Box	Model parts	Lag	Estimate	SE	t	P
Worldwide	(0, 1, 1) (0, 0, 0)	4.227	0.299	Difference		1			
				MA	1	0.505	0.080	6.291	< 0.001
USA	(0, 1, 1) (0, 0, 0)	2.526	0.787	Difference		1			
				MA	1	0.583	0.077	7.564	< 0.001
Canada	(0, 1, 1) (0, 0, 0)	3.611	0.871	Difference		1			
				MA	1	0.622	0.073	8.546	< 0.001
Egypt	(1, 0, 9) (0, 0, 0)	5.342	0.002	AR	1	0.580	0.122	4.742	< 0.001
				MA	1	0.360	0.139	2.582	0.011
					9	-0.630	0.108	-5.811	< 0.001
India	(1, 0, 1) (0, 0, 0)	1.765	0.475	AR	1	0.996	0.020	50.335	< 0.001
				MA	1	0.888	0.075	11.813	< 0.001
UK	(1, 0, 7) (0, 0, 0)	1.817	0.145	AR	1	0.991	0.016	61.728	< 0.001
				MA	1	1.009	0.046	22.060	< 0.001
					7	-0.155	0.048	-3.244	0.002

SE: Standard error; ARIMA: Autoregressive integrated moving average; MA: Moving average component; AR: Autoregressive component; BIC: Bayesian information criterion; USA: United States of America; UK: United Kingdom

In Egypt, an overall general decrease in interest in SDF was detected, albeit with some transitory increases in RSV values. Interest in SDF was stable overall in the UK, despite transient decreases in RSV. Table 2 summarises the fit statistics of the 12-month ARIMA forecasting models of interest in SDF.

Discussion

The results of the present study indicate an increase in interest among Google users regarding SDF-related information over the last decade. Although it has some limitations, Google Trends can be used in epidemiological studies due to the large amounts of data that are available.[18] Many studies have been conducted in the field of medicine using this method.[22,24,25] However, there have been few such studies in the field of dentistry.[19-21] This is the first study to investigate interest in a dental material or a treatment method using Google Trends data. In this study, we aimed to determine how much interest in this novel material, which was reported to be effective in arresting caries, has been received worldwide.

Interest in the use of SDF has been growing. SDF has been used as an alternative treatment for caries prevention and treatment.[26] The use of ammoniacal silver fluoride for preventing dental caries was pioneered by Nishino et al. in Japan, who developed this material to exploit the benefits of both Ag^+ and F^-. Thus, the first SDF product was approved in 1970.[27] Then, other similar products became commercially available in other regions, including 40% silver fluoride in Australia, Argentina, and Brazil.[28] Since 2002, many clinical trials have demonstrated the efficacy of SDF and its comparative effectiveness with other chemopreventive agents and interventions.[28,29]

SDF has been used worldwide, except in the USA, for > 80 years.[2] SDF was approved by the USFDA as a treatment for dentinal sensitivity in 2014, with reports of its effectiveness leading to growing interest.[4,30] SDF had been used off-label for caries prevention; however, it was recently approved as an interim caries-preventing medicament.[26] Consistent with this, the present study showed that interest in SDF has increased worldwide during the last decade, especially since 2014 in accordance with USFDA approval. We found that the highest number of searches for SDF occurred in the USA and Canada, likely due to the availability of SDF-containing products in those countries, and support of its use for the management of caries in primary dentition by organisations such as the AAPD and the World Health Organisation (WHO).[6,31]

A solution of 38% SDF has been reported to be effective for caries prevention.[12] SDF is usually recommended for children at high risk of developing caries, who often endure poor living conditions and reside in developing countries.[26,32] A review concluded that SDF was an effective, efficient, equitable, and safe caries-preventing agent that appears to meet the standards of the US Institute of Medicine (IOM) and the Millennium Goals of the WHO.[33]

Numerous recent systematic reviews indicated that the application of SDF could prevent dental caries in children, and SDF has been shown to be 89% (range: 49%-138%) more effective in preventing caries in deciduous teeth than other active treatments or placebo.[13,14,26,34] Despite the good results reported in clinical studies, SDF has not been accepted as a routine treatment method worldwide. There are a number of barriers to the adoption of any new therapeutic approach. For example, tuition regarding the use of SDF has not been provided in most dental schools, and has only recently become a topic of interest for paediatric dentistry residencies.[15] Other common barriers to adopting new treatments and therapies include concerns regarding efficacy, safety, variation in clinical trial methodologies, lack of clear treatment guidelines, regulatory issues, patient attitudes, and potential reimbursement claims.[5] The most frequently reported barrier to the use of SDF is a lack of parental acceptance, due to the staining of the teeth caused by SDF application (i.e., poor aesthetic outcomes). Off-label use, training, difficulty in procuring the product, and high cost represent additional barriers to the use of SDF.[15] The use of SDF will likely become more widespread with additional evidence-based clinical studies, greater availability of SDF-containing products worldwide, and coverage of SDF in the curricula of dental schools.

This study had some limitations. First, in some countries, Google is not a widely-used search engine. However, as data from other web search engines used in such countries could not be obtained, only data from Google were used. Also, although the searches were performed in various languages, some languages and countries were excluded due to a lack of data. Therefore, at present, collecting and analysing big data on web activity cannot adequately replace traditional epidemiological methods.[21]

Despite these limitations, many studies have shown that Google Trends data correlated well with traditional surveillance data.[8-14] These studies indicated the potential utility of Google Trends data in terms of their amenability to being obtained quickly, easily, and at little cost, compared with conventional methods.[24,35] In the future, comparing the data obtained from traditional methods with Google Trends data will provide clarification of the subject.

Conclusion

The results of the present study indicated that there has been an increase in interest among Google users regarding SDF-related information over the last decade. This increase began in 2014, and the highest number of searches were performed in the USA and Canada, probably due to approval by the USFDA, the launch of SDF-containing products in the USA, and support for their use by the AAPD and the WHO. SDF use will likely increase worldwide with additional evidence-based clinical studies, the licensing of SDF as a caries-preventing agent, and its inclusion in dental education curricula.

Conflict of Interests

Authors have no conflict of interest.

Acknowledgments

None.

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