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Original Research (Preprint)

Effects of Drinking Water Calcium, Magnesium, and Fluoride Concentrations on Dental Caries among Mongolian Children under 5 Year Old

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Abstract:
Dental caries remains a major public health challenge among children in Mongolia. The chemical composition of drinking water plays a crucial role in caries prevention. Fluoride influences the balance of enamel mineralization by forming fluorapatite on acid-exposed enamel surfaces, thereby reducing enamel solubility. Moreover, fluoride inhibits the acidogenic metabolism of cariogenic bacteria such as Streptococcus mutans within the dental biofilm. Therefore, understanding the relationship between drinking water, mineral content, and dental caries is essential for developing effective preventive strategies. Objective: To determine the prevalence and mean score of dental caries among children under 5 years old, covering 21 provinces of Mongolia, and to evaluate the effects of selected drinking water minerals (calcium, magnesium, and fluoride) on dental caries.
This study utilized oral examination data from 118,153 children under 5 years old residing in 321 soums from all 21 provinces and the capital city (Ulaanbaatar) of Mongolia. Dental caries was assessed according to the World Health Organization (WHO) caries diagnostic criteria. The associations between drinking water mineral concentrations and dental caries were analyzed using linear regression models.
The prevalence and mean score of dental caries ranged 63.5%-66.2% and 3.0-3.1 among 5-year-old children, respectively. Boys had a slightly higher score (3.17 ± 3.52) than girls (2.92 ± 3.40). Regression analysis revealed that fluoride ($\beta = -0.449$, $p < 0.001$) and magnesium ($\beta = -0.031$, $p < 0.001$) concentrations in drinking water were significantly associated with lower levels of dental caries, indicating a protective effect on dental caries.
Fluoride and magnesium in drinking water appear to be important protective factors of dental caries, whereas calcium did not demonstrate a consistent association. These findings highlight the potential importance of drinking water mineral composition in the prevention of childhood dental caries in Mongolia.

Keywords: Fluoride; Magnesium; Calcium; Dental Caries

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Introduction

Dental caries is the most prevalent oral disease among children worldwide. Despite numerous efforts to promote and improve children's oral health, the prevalence of dental caries remains above 50% in many countries. The World Health Organization (WHO) reported that 60–90% of children and adolescents in developed countries are affected by dental caries. (Lam, 2014) A review of the literature indicates that dental caries is a multifactorial disease influenced by numerous biological, behavioral, and environmental factors. (Lempert et al., 2014)

Fluoride, an essential element for oral health, is highly reactive and therefore does not occur freely in nature. It is commonly found in groundwater in its ionic form. Fluoride plays a critical role in the prevention of dental caries; however, excessive exposure during tooth development may lead to dental fluorosis. Early manifestations of fluorosis typically affect the incisors and premolars, whereas severe forms may involve skeletal tissues. The optimal fluoride concentration in drinking water ranges from 0.8 to 1.2 mg/L (ppm), and the recommended daily fluoride intake for adults is approximately 3 mg, including 0.5–1.1 mg from food and 2.2–2.5 mg from drinking water. (Horowitz, 1996) In Mongolia, approximately 47.7% of the population consumes drinking water with insufficient fluoride concentrations.

Numerous studies have investigated the prevalence and mean score of dental caries in Mongolia; however, considerable variation exists in study design, framework and sample. Over the past three decades, studies among preschool children have reported a high burden of dental caries in Mongolia. The prevalence and mean score of the dental caries were 78.5% and 4.9 among 3–5 years old children. (Oyunbat B, 1993) the mean score was 5.3 in 3–5 years old, (Мөнгөнцэцэг Л, 2001) 96.1% and 8.1 among 4–6 years old, (Oyuntsetseg B, 2005) 87.8% and 7.5 among 3–5 years old, (Hulan et al., 2010) 87.0% and 5.9 in Ulaanbaatar; 70.8% and 3.0 in rural areas among 5-year-old, (Дэмбэрэлсүрэн Ж et al., 2011) 94.3% and 8.3 among 3-year-old children, (Дэлгэрцэцэг Ж 2015a) 91.8% and 8.1 among 4-year-old children,(Дэлгэрцэцэг Ж, 2015b) respectively. Studies conducted in Ulaanbaatar (2016) reported prevalence rates ranging from 85% to 93% and mean caries score from 6.2 to 8.2 among children aged 3–5 years. (Дэлгэрцэцэг Ж, 2016; Сувданчимэг А et al., 2016) In 2018, the national study results reported that were 82.9% and 5.9 among 5-year-old children, (Delgertsetseg J et al., 2018) while in 2020 the corresponding figures in Ulaanbaatar were 85% and 6.2. (Сувданчимэг А et al., 2020)

Chemical composition of drinking water, whether naturally occurring or resulting from human activities, have been shown to exert substantial effects on oral tissues, including teeth and oral mucosa. (J. Kavitha et al., 2020) Fluoride has been used in dentistry for more than 70 years and is recognized as one of the most effective measures for preventing dental caries. Nevertheless, excessive fluoride exposure during the tooth developmental stage may increase the risk of fluorosis. Therefore, a comprehensive understanding of fluoride's mechanisms of action is necessary to maximize its preventive benefits while minimizing adverse effects.

Since the 1980s, fluoride has been recognized primarily as a topical agent in caries prevention. (Moreno et al., 1977) At low concentrations in the oral environment, fluoride adsorbs onto the surface of apatite crystals, thereby inhibiting enamel demineralization. When salivary pH returns to neutral levels, fluoride promotes supersaturation with respect to fluor hydroxyapatite, accelerating the remineralization process. (Koulourides & Cameron, 1980) The newly formed mineral contains higher fluoride and lower carbonate concentrations, making enamel more resistant to future acid challenges. In addition, fluoride reduces the virulence of cariogenic bacteria such as Streptococcus mutans by inhibiting acid production and glucan synthesis. (Buzalaf et al., 2011)

Materials and Methods

This study was conducted within the framework of the "Preventive Screening and Early Detection Program" funded by the Ministry of Health of Mongolia. A total of 421,970 children aged 0–17 years from 321 soums across all 21 provinces of Mongolia participated in the program. For the present analysis, oral health examination data from 118,153 children aged under 5 years old were included.

Dental caries were assessed according to the standardized criteria recommended by the WHO. Information on the mineral composition of drinking water was obtained from the databases of the National Agency for Meteorology and Environmental Monitoring and the National Center for Public Health through the online surveillance platform (www.tandalt.mn), using data collected between 2020 and 2023.

The effects of selected drinking water minerals, including calcium (Ca), magnesium (Mg), and fluoride (F), on dental caries were evaluated using linear regression analysis. Statistical analysis was done using SPSS software version 26.

Results

The prevalence of dental caries and dental treatment needs increased progressively with age. The prevalence of dental caries and dental treatment needs were 1.1% and 1.0% among children under 1 year old; 7.4% and 7.1% at 1 year of age; 24.8% and 23.4% at 2 years; 43.2% and

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40.5% at 3 years; 57.3% and 52.7% at 4 years, respectively. The highest values were observed among 5-year-old children, for whom 64.8% and 59.3% (Figure 1).

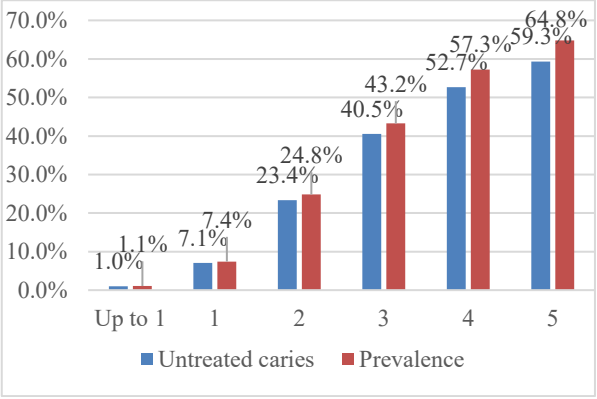

Figure 1. Prevalence of Dental Caries and Dental Treatment Needs among Children Aged under 5 Years Old in Mongolia.

We determined the mean caries score and compared it between all provinces in Mongolia. The highest dmft score was observed in Umnugovi (2.29), Zavkhan (2.28), Arkhangai (2.18), and Ulaanbaatar (2.08), whereas the lowest values were recorded in Bayan-Ulgii (0.83), Sukhbaatar (0.89), Dundgovi (0.91), and Khuvsgul (1.01). Across all provinces, the dmft index ranged from 0.83 to 2.29, indicating substantial regional variation in dental caries score among children. (Figure 2)

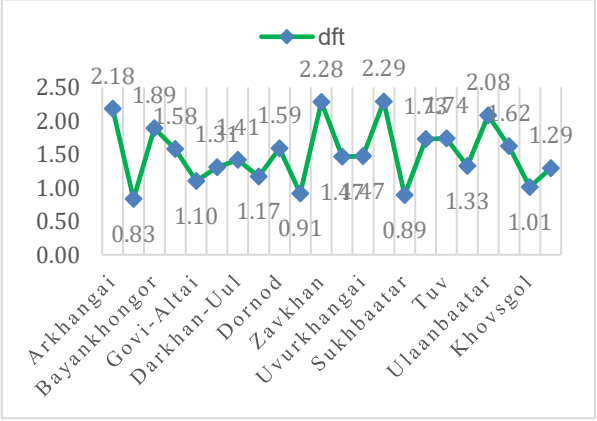

Figure 2. Dental Caries Score among Children Aged Under 5 Years Old in Mongolia

The map demonstrates substantial variation in the prevalence of the dental caries across the provinces and the capital city of Mongolia. The highest prevalence was observed in Arkhangai (79.4%), followed by Zavkhan (75.7%), Umnugovi (71.2%), Ulaanbaatar (69.9%), Bayankhongor (69.3%), and Tuv Province (68.5%). In contrast, the lowest prevalence rates were recorded in Darkhan-Uul (49.3%) and Bayan-Ulgii (49.4%), while relatively low levels were also observed in Sukhbaatar (50.2%), Dornogovi (51.2%), Dundgovi (51.4%), and Khentii (51.4%). In most of the provinces, the dental caries prevalence ranged between 50% and 70%, with several western and central provinces exhibiting levels above the national average. These regional variations suggest that factors such as population density, environmental conditions, and lifestyle characteristics may influence the observed distribution and warrant further investigation (Figure 3).

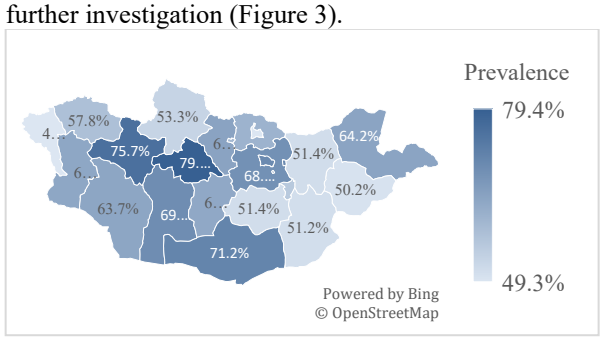

Figure 3. Prevalence of Dental Caries among 5-Year-Old Children in the Provinces of Mongolia

When analyzed by age group, the mean numbers of decayed, filled, extracted teeth and the overall caries experience showed a distinct age-related pattern. Among children aged 0–2 years, the mean number of decayed teeth was relatively low (0.03–0.75). However, a marked increase was observed between 3 and 6 years of age. At 5–6 years, the mean number of untreated decayed teeth increased from 2.42 ± 3.05 to 2.60 ± 3.01, while the mean caries experience (dmft) increased from 3.04 ± 3.47 to 3.42 ± 3.45, reaching its highest level. These findings indicate a substantial burden and rapid progression of dental caries in the primary dentition during early childhood (Table 1).

Table 1. Dental Caries Score among Children Aged Under 5 Years Old in Mongolia

Age	Decayed	Filled	Missed	Dmft
Up to 1	0.03±0.35	0.01±0.11	-	0.03±0.39
1	0.19±0.90	0.02±0.26	-	0.22±0.98
2	0.75±1.79	0.11±0.62	-	0.86±2.00
3	1.48±2.50	0.27±0.94	-	1.74±2.80
4	2.04±2.86	0.48±1.23	-	2.52±3.24
5	2.42±3.05	0.62±1.39	-	3.04±3.47

The calcium concentration in drinking water varied considerably across the study areas, ranging from 24.98 to 64.92 mg/L. The highest level was observed in Selenge Province (64.92 mg/L), while the lowest level was recorded in Ulaanbaatar (24.98 mg/L) (Figure 4).

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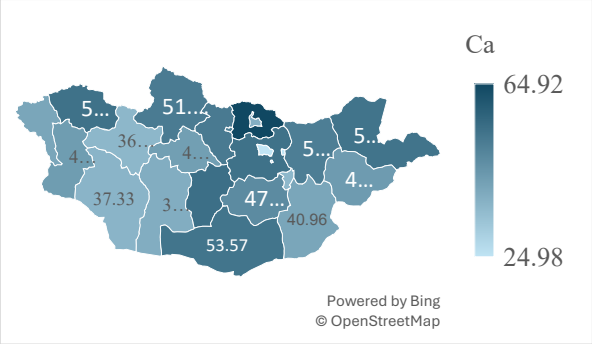

Figure 4. Calcium Concentrations in Drinking Water across the Provinces of Mongolia.

The magnesium concentration in drinking water showed substantial regional variation, ranging from 5.88 to 43.78 mg/L. The highest levels were detected in Sukhbaatar (43.78 mg/L) and Govi-Altai (43.54 mg/L) provinces, while the lowest level was recorded in Ulaanbaatar (5.88 mg/L) (Figure 5).

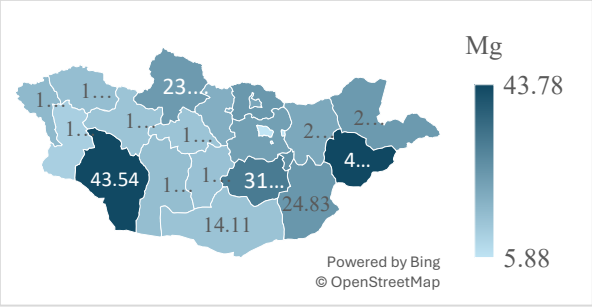

Figure 5. Magnesium Concentrations in Drinking Water across the Provinces of Mongolia.

Fluoride concentrations in drinking water exhibited considerable regional variation, ranging from 0.25 to 2.52 mg/L. The highest levels were detected in Dundgovi (2.52 mg/L), Dornogovi (2.25 mg/L), and Govisumber (1.92 mg/L) provinces, while the lowest levels were observed in Bayan-Ulgii (0.25 mg/L) and Ulaanbaatar (0.42 mg/L) (Figure 6).

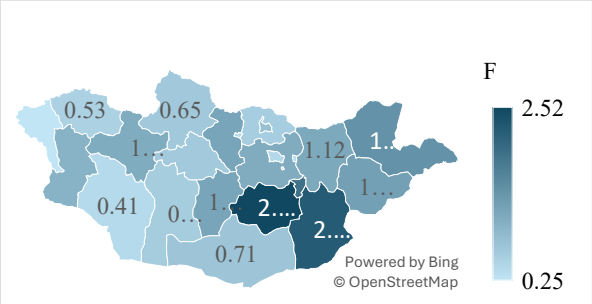

Figure 6. Fluoride Concentrations in Drinking Water across the Provinces of Mongolia.

A multivariable linear regression analysis was performed to assess the association between drinking water mineral concentrations and dental caries score among children aged under 5 years old in Mongolia. The regression constant was 2.237. Fluoride (F) in drinking water showed a significant negative association with dental caries score; for each one-unit increase in fluoride concentration, the dmft score decreased by 0.252 teeth ($B = -0.252$, $\beta = -0.056$, $p < 0.001$).

Magnesium (Mg) also demonstrated a significant protective effect against dental caries, with each one-unit increase associated with a reduction of 0.025 dmft units ($B = -0.025$, $\beta = -0.101$, $p < 0.001$). The standardized regression coefficient indicated that magnesium exerted a stronger protective effect than fluoride.

In contrast, calcium (Ca) showed a weak positive association with dental caries score; however, this relationship was not statistically significant ($B = 0.001$, $\beta = 0.007$, $p = 0.063$). These findings suggest that fluoride and magnesium in drinking water are significant protective factors against dental caries, whereas calcium does not appear to have a significant effect on caries score in this population (Table 2).

Table 2. Multivariable Linear Regression Analysis of the Association between Drinking Water Mineral Concentrations and Dental Caries Score in the Primary Dentition

	B	St.d	Beta	p value
Constant	2.237	0.022		0.000
Fluoride	-0.252	0.018	-0.056	0.000
Calcium	0.001	0.001	0.007	0.063
Magnesium	-0.025	0.001	-0.101	0.000

Discussion

In the present study, fluoride (F) and magnesium (Mg) concentrations in drinking water were associated with dental caries score during the primary dentition stages. These findings are consistent with previous international studies demonstrating the protective role of fluoride and magnesium for dental caries. Regions with higher fluoride concentrations in drinking water have been reported to exhibit significantly lower levels of dental caries among children. (Petersen & Lennon, 2004)

The inverse association observed between fluoride concentration and dental caries score in our study is consistent with the well-established role of fluoride in inhibiting enamel demineralization and enhancing remineralization. Similarly, magnesium demonstrated an even stronger protective effect, which may be explained by its potential contribution to salivary buffer capacity and maintenance of oral mineral balance, as suggested by previous studies.

In contrast, calcium showed a weak positive association with dental caries score, although this relationship was not statistically significant. While

calcium did not emerge as a significant predictor of dental caries, the observed tendency toward increased caries score may reflect the influence of higher mineral and salt concentrations in drinking water on the oral environment. Previous studies have suggested that elevated mineral content in drinking water may affect oral pH and related ecological factors, which could indirectly influence caries development. (Iheozor-Ejiofor et al., 2015)

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Author's Contributions

B.G.: Conceptualization and study design, methodology, data collection, writing - original draft preparation, G.Y., K.T.: Investigation, data curation, formal analysis, B.B., E.B.: Investigation, data curation, formal analysis and validation, O.E., D.J.: Conceptualization and study design, writing - review and editing, supervision.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest to disclose.

Data Availability Statement

The datasets generated and analyzed during the current study are not publicly available due to institutional and national regulations on patient data protection but are available from the corresponding author on reasonable request.

Ethics

This study received ethics approval from the Mongolian National University of Medical Sciences in Ulaanbaatar, Mongolia (2023/3-07).

References

Buzalaf, M. A. R., Pessan, J. P., Honório, H. M., & ten Cate, J. M. (2011). *Mechanisms of Action of Fluoride for Caries Control* (pp. 97–114). https://doi.org/10.1159/000325151

Delgertsetseg J, Oyuntsetseg B, Munkh-Od Sh, Suvdanchimeg A, & Amarsaikhan B. (2018). The results of National Oral Health Survey, Mongolia. *Central Asian Journal of Medical Sciences*, *4*(1), 61–68.

Horowitz, H. S. (1996). The Effectiveness of Community Water Fluoridation in the United States. *Journal of Public Health Dentistry*, *56*(5), 253–258. https://doi.org/10.1111/j.1752-7325.1996.tb02448.x

Hulan, U., Sarantuya, J., Tselmeg, B., & Soyolmaa, M. (2010). Detection of mutans streptococci in plaque samples from Mongolian preschool and school children. *Pediatric Dental Journal*, *20*(2), 171–176. https://doi.org/10.1016/S0917-2394(10)70209-3

Iheozor-Ejiofor, Z., Worthington, H. V., Walsh, T., O'Malley, L., Clarkson, J. E., Macey, R., Alam, R., Tugwell, P., Welch, V., & Glenny, A. M. (2015). Water fluoridation for the prevention of dental caries. In *Cochrane Database of Systematic Reviews* (Vol. 2015, Number 6). John Wiley and Sons Ltd. https://doi.org/10.1002/14651858.CD010856.pub2

J. Kavitha, S. Sivakrishnan, S. L. Sree, & S. Srinivasan. (2020). Pollution in dentistry – a critical review. *International Journal of Pharmaceutical Sciences and Research*, *11*(7), 3069–3077.

Koulourides, T., & Cameron, B. (1980). Enamel remineralization as a factor in the pathogenesis of dental caries. *Journal of Oral Pathology & Medicine*, *9*(5), 255–269. https://doi.org/10.1111/j.1600-0714.1980.tb00383.x

Lam, A. (2014). Elements in oral health programs. *The New York State Dental Journal*, *80*(2), 26–30. http://www.ncbi.nlm.nih.gov/pubmed/24851389

Lempert, S. M., Froberg, K., Christensen, L. B., Kristensen, P. L., & Heitmann, B. L. (2014). Association between body mass index and caries among children and adolescents. *Community Dentistry and Oral Epidemiology*, *42*(1), 53–60. https://doi.org/10.1111/cdoe.12055

Moreno, E. C., Kresak, M., & Zahradnik, R. T. (1977). Physicochemical Aspects of Fluoride-Apatite Systems Relevant to the Study of Dental Caries. *Caries Research*, *11*(1), 142–171. https://doi.org/10.1159/000260299

Oyunbat B. (1993). Oraler Gesuhdnietszustand bei mongolischen Kindern und Empfehlungen zur Optimieriung des zahnarztlichen Betzeuings systems. *Diisertation*.

Oyuntsetseg B. (2005). Caries prediction using salivary buffer capacity test and caries activity test in Mongolian preschool children. *Dissertation*.

Petersen, P. E., & Lennon, M. A. (2004). Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. *Community Dentistry and Oral Epidemiology*, *32*(5), 319–321. https://doi.org/10.1111/j.1600-0528.2004.00175.x

Дэлгэрцэцэг Ж. (2016). Сургуулийн өмнөх насны хүүхдийн шүд цоорох өвчин ба биеийн өсөлтийн зарим үзүүлэлтийн хамаарал. *Анагаах Ухааны Докторын Зэрэг Хамгаалсан Нэг Сэдэвт Бүтээл*.

Дэлгэрцэцэг Ж, & Оюунцэцэг Б. (2015a). Улаанбаатар хотын 3 настай хүүхдийн шүд цоорох өвчин ба биеийн өсөлтийн үзүүлэлтийн хамаарлыг судалсан дүн. *Innovation Dentistry*, *1*(1), 22-25`.

Дэлгэрцэцэг Ж, & Оюунцэцэг Б. (2015b). Улаанбаатар хотын 4 настай хүүхдийн шүд цоорох өвчин ба биеийн өсөлтийн үзүүлэлтийн хамаарлыг судалсан дүн. *Эрүүл Мэндийн Шинжлэх Ухаан*, *11, 2*(34), 114–119.

Дэмбэрэлсүрэн Ж, Оюунбат Б, Соёлмаа М, Үржинлхам Ж, Уранчимэг Д, & Одончимэг Д. (2011). *Улаанбаатар хотын хүүхэд залуусын амны хөндийн өвчлөлийн судалгаа*. 37–41.

Мөнгөнцэцэг Л. (2001). Шүд цоорох өвчнөөс урьдчилан сэргийлэх, эмчлэхэд ургамлын гаралтай зарим бэлдмэлийг хэрэглэх асуудалд. *Анагаах Ухааны Докторын Зэрэг Хамгаалсан Нэг Сэдэвт Бүтээл*.

Сувданчимэг А, Дэлгэрцэцэг Ж, Мөнх-Од Ш, Цэлмэг Б, & Оюунцэцэг Б. (2016). Сургуулийн өмнөх насны хүүхдийн шүд цоорох өвчний байдал. *Innovation Dentistry*, *2*(1), 26–28.

Сувданчимэг А, Цэлмэг Б, Мөнх-Од Ш, Дэлгэрцэцэг Ж, Номин Г, & Оюунцэцэг Б. (2020). Эцэг эхийн амны хөндийн эрүүл мэндийн мэдлэг ба хүүхдийн шүд цоорох өвчин. *Нүүр Ам Судлал*, *2*, 22–27.