Comparative Evaluation of Kara-Shoro Mineral Water and Its Influence on Dental Hard Tissue Integrity: A Community-Based Intervention Study.

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ABSTRACT

Background: Dental caries remains highly prevalent among children in rural regions of Kyrgyzstan, where drinking water contains low fluoride levels. The Uzgen district of Osh region is characterized by fluoride deficiency, which may contribute to the increasing burden of dental disease. The Kara-Shoro mineral spring contains naturally high concentrations of ionic fluoride and was evaluated as a potential component of a comprehensive caries-prevention program.

Objectives: To assess the baseline oral health status of schoolchildren in three rural villages and to evaluate the effectiveness of endogenous use of Kara-Shoro mineral water as part of a multi-component caries-prevention program.

Materials and Methods: A total of 740 schoolchildren from On-Besh Zhash, Ak-Terek and Salamalik villages underwent preventive dental examinations. Drinking-water fluoride concentrations were determined in each village. A prospective study was carried out among 120 children aged 7–16 years, assigned to intervention and control groups. The intervention included health education, therapeutic care, professional hygiene and daily endogenous intake of Kara-Shoro mineral water (130 ml/day) for three years. Outcomes assessed included caries intensity (KPI/kpi), permanent-surface caries indices (CPUp), oral hygiene index (GI), enamel remineralization time, and enamel solubility. Statistical analyses were performed using SPSS 13.0.

Results: Rehabilitation needs were high across all villages (75–80 percent), and fluoride levels in drinking water ranged from 0.216 to 0.287 mg/L. In the intervention group, caries intensity decreased from 3.00 ± 0.27 to 1.62 ± 0.19 over three years, while the control group showed an increase from 3.32 ± 0.44 to 4.53 ± 0.38. Oral hygiene improved significantly in the intervention group (GI from 2.83 ± 0.05 to 1.74 ± 0.10), with only minor changes in controls. Enamel remineralization time decreased to 2.12 ± 0.19 days in the intervention group compared with 4.28 ± 0.36 days in controls. Enamel solubility declined by more than half among children receiving mineral water, while no improvement was observed in the control group.

Conclusion: Children in the Uzgen district demonstrate a high burden of dental caries associated with low environmental fluoride exposure. Endogenous use of Kara-Shoro mineral water, integrated into a comprehensive preventive program, improved oral hygiene, enhanced enamel resistance and significantly reduced caries intensity over three years. The findings support the inclusion of naturally fluoridated mineral water as a feasible preventive measure in fluoride-deficient regions...

Keywords: Dental caries; Fluoride deficiency; Kara-Shoro mineral water; Children; Prevention; Enamel remineralization; Oral hygiene

How to cite this article: Eshiev AM, Eshiev DA, Taalaibekov NT, Toktombaev MA, Azimbaev NM., Comparative Evaluation of Kara-Shoro Mineral Water and Its Influence on Dental Hard Tissue Integrity: A Community-Based Intervention Study...Int J Drug Deliv Technol. 2026;16(1s): 1273-1277; DOI: 10.25258/ijddt.16. 1273-1277

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Dental caries remains one of the most persistent public health challenges in Kyrgyzstan, and recent data show that its incidence continues to rise across all age groups [1]. Communities throughout the country live under demanding environmental conditions and ongoing technogenic pressures, which together create an unfavorable background for oral health [2]. This growing burden of caries

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underscores the need for stronger and more effective preventive solutions. Researchers in Kyrgyzstan and abroad are actively working to refine and expand evidence-based methods of prevention and treatment [3]. Current international and national guidelines emphasize fluoride exposure, consistent oral hygiene, and a balanced diet with limited carbohydrate intake as the cornerstones of prevention [4]. Many experts note that among these, fluoride remains the most influential factor in reducing caries rates, particularly in economically developed countries [5].

Fluoride-based preventive strategies are now a standard component of community oral health programs. Both local and systemic fluoride applications have been shown to significantly decrease dental morbidity in many regions of the world, including [6] . In the Osh region, however, naturally low fluoride levels in the environment may be contributing to the persistently high prevalence of caries. This makes primary prevention particularly important. One promising direction is the use of natural resources, especially mineral waters that contain fluoride [7]. Several studies describe the preventive value of such waters. The Kara Shoro deposit in Uzgen district is a rare source of drinking water with a naturally high fluoride concentration. Its mineral composition provides active ions in bioavailable form, giving it potential advantages over artificially created agents for both exogenous and endogenous caries prevention [8].

Given these factors, studying the effect of Kara Shoro mineral water on oral tissues and evaluating its use in caries prevention among children in the Osh region is both timely and relevant. The aim of the study was to enhance the prevention of dental caries in children by incorporating the fluoride-containing mineral water Kara Shoro into a comprehensive preventive program.

MATERIALS AND METHODS

2.1 Study population*:* The study assessed the dental status of 740 school-aged children living in rural areas of the Uzgen district of the Osh region. Participants were recruited from three schools located in the villages of Onbesh Zhash, Ak Terek, and Salamalik. A prospective component was carried out in a subset of 120 children aged 7 to 16 years who lived under similar household and environmental conditions and were monitored closely by their parents. Selection of study sites and participants was aligned with the objectives of evaluating oral health in fluoride-deficient regions.

2.2 Assessment of dental status*:* Dental examinations included clinical, paraclinical, and laboratory methods. Caries prevalence and caries intensity were recorded using standard diagnostic criteria. Oral hygiene status, cariesogenicity of dental plaque, and the rate of enamel remineralization were assessed using validated indices and established methodological protocols.

2.3 Preventive intervention*:* A comprehensive caries prevention program was implemented in 120 pupils from Ak Terek and Salamalik schools. Children in the intervention group (n=30 per age category) received endogenous caries prevention through regular consumption of natural mineral water from the Kara Shoro source, which contains a naturally high fluoride concentration. Each child received 130 ml of mineral water daily. Intake was performed under parental supervision following a standardized protocol. In the morning, the children used Kara Shoro mineral water for routine oral rinsing, and the scheduled consumption time was set at 17:00. A control group consisting of children of the same age and attending the same schools did not receive Kara Shoro mineral water. The preventive intervention lasted three years.

2.4 Statistical analysis: Data processing and statistical analysis were conducted using SPSS version 13.0. Descriptive and inferential statistical methods were applied depending on the distribution and nature of the variables. Graphs and tables were prepared using Microsoft Excel. All analyses were performed on a personal computer running Windows XP.

3. RESULTS

3.1 Population screening and baseline dental status

Preventive dental examinations were performed among 740 schoolchildren from three villages in the Uzgen district (On-Besh Zhash, Ak-Terek, Salamalik) attending three schools (Tashtankul Borubaev Secondary School No. 79; Ak-Terek Secondary School No. 62; Rayymbek Satybaldy uulu Secondary School No. 32). Examination counts and key findings by locality were as follows:

On-Besh Zhash (n = 210): 96 (45.7%) children were in the mixed-dentition period (6–10 years). Rehabilitation needs were identified in 160 (76.1%). In the permanent dentition 89 (55.6%) had caries, 71 (44.3%) had complicated caries, 39 (18.5%) had filled teeth, and only 11 (5.2%) had intact dentition.

Ak-Terek (n = 202): 76 (37.6%) were in the mixed-dentition period. Rehabilitation needs were identified in 153 (75.7%). In the permanent dentition 85 (55.5%) had caries, 52 (33.9%) had complicated caries, 10 (6.5%) had filled teeth, and 6 (3.9%) had intact dentition.

Salamalik (n = 328): 139 (42.3%) were in the mixed-dentition period. Rehabilitation needs were identified in 263 (80.0%). In the permanent dentition 32 (9.7%) had caries, 17 (5.1%) had complicated caries, 13 (3.9%) had filled teeth, and 3 (0.9%) had intact dentition.

Overall, 576 (77.9%) of the 740 screened children required rehabilitation; 164 children (22.1%) received rehabilitation. The distribution of caries and complicated caries was highest in Salamalik compared with Ak-Terek and On-Besh Zhash, and rehabilitation needs were concentrated in the mixed-dentition period.

To summarize the key baseline indicators and the main outcomes of the intervention, the essential data from the three examined villages and the two study groups are presented in **Table 1**. The table highlights the consistently high rehabilitation needs among children in all surveyed settlements, the low fluoride concentrations in local drinking water, and the principal shifts in caries intensity, oral hygiene status, and enamel remineralization observed during the three-year preventive program. These indicators provide a consolidated view of the initial oral health conditions and the comparative effectiveness of the Kara-Shoro intervention relative to the control group.

Table 1. Table 1. Key Oral Health Indicators, Water Fluoride Levels, and Intervention Outcomes

Parameter	On-Besh Zhash	Ak-Terek	Salamalik	Intervention Group	Control Group
Children examined (n)	210	202	328	120	120
Rehabilitation needed (%)	76.1	75.7	80.0	–	–
Permanent caries (%)	55.6	55.5	9.7	–	–
Fluoride in water (mg/L)	0.287	0.264	0.216	–	–
KPI/kpi baseline (mean ± SD)	–	–	–	3.00 ± 0.27	3.32 ± 0.44
KPI/kpi after 3 years	–	–	–	1.62 ± 0.19	4.53 ± 0.38
Oral hygiene index baseline	–	–	–	2.83 ± 0.05	2.77 ± 0.30
Oral hygiene index final	–	–	–	1.74 ± 0.10	2.30 ± 0.19
Enamel remineralization (days), baseline	–	–	–	4.30 ± 0.36	3.52 ± 0.35
Enamel remineralization (days), final	–	–	–	2.12 ± 0.19	4.28 ± 0.36

3.2 Fluoride content of drinking water

Laboratory analysis of drinking water from open sources in the three villages (performed in the central research laboratory, Kara-Balta) showed low fluoride concentrations: Ak-Terek — 0.264 mg/L; Salamalik — 0.216 mg/L; On-Besh Zhash — 0.287 mg/L. All measured values were below 0.30 mg/L and therefore substantially lower than the commonly cited optimal range (0.5–1.0 mg/L). These data indicate a marked fluoride deficiency in local drinking water sources.

3.3 Geographic and physico-chemical characteristics of Kara-Shoro mineral spring

The Kara-Shoro deposit comprises multiple source areas and yields carbon dioxide-bearing mineral waters. The spring was classified on the basis of macrocomponent composition as a bicarbonate–chloride–sodium type (intermediate between Arzni and Yessentuki-4 types); it is characterized as a cold spring with long shelf stability under storage conditions. Measured mineralization and flow parameters, and the presence of microcomponents (lithium, bromine, barium, zinc, iron, fluoride, sulfates, silicic acid), were noted. The mineral composition and naturally elevated ionic fluoride content motivated study of Kara-Shoro as an endogenous preventive agent for dental caries.

3.4 Implementation of the comprehensive preventive program and compliance

A comprehensive prevention program was delivered to 120 schoolchildren (intervention cohort) drawn from Ak-Terek and Salamalik. The intervention included health education, therapeutic treatment where indicated, professional hygiene, and endogenous administration of Kara-Shoro mineral water (daily dose 130 mL) under parental supervision. A contemporaneous control group of children of the same age did not receive Kara-Shoro. The preventive measures were implemented over a three-year period.

3.5 Changes in caries intensity and prevalence during follow-up

At baseline, the aggregate caries prevalence in the pilot facility averaged 77.9%. Caries intensity (KPI + kpi) at baseline was 3.00 ± 0.27 in the main (intervention) group and 3.32 ± 0.44 in the control group. Over the first year there were small, non-significant increases in both groups (main: 3.00 → 3.14; control: 3.32 → 3.46; $p > 0.05$). By 1.5 years (March 2022) the main group showed a decrease (to 2.86 ± 0.21) while the control group increased (to 3.81 ± 0.23); differences between groups reached statistical significance ($p < 0.05$). At 2 years the main group continued to decline (2.86 → 1.98) while the control group increased (3.81 → 4.01) ($p < 0.05$). At study completion (3 years) the main group index was 1.62 ± 0.19 versus 4.53 ± 0.38 in the control group ($p < 0.01$). The cumulative increase in carious cavities over the study period averaged 0.46 cavities in the main group versus 2.72 cavities in the control group ($p < 0.001$); the reported final reduction in caries in the main group was 83.09%.

When permanent-dentition surface indices (CPUp/KPUp) were considered, baseline values were 0.08 ± 0.16 (main) and 0.86 ± 0.15 surfaces (control). Over sequential follow-ups the CPUp in the main group showed smaller increases and eventual declines compared with pronounced increases in the control group; by the culmination of prevention the CPUp was 0.52 ± 0.18 (main) versus 3.44 ± 0.68 (control) ($p < 0.001$).

3.6 Oral hygiene and plaque cariesogenicity

At baseline, oral hygiene was poor across the cohort (hygiene index > 2.6): mean GI 2.83 ± 0.05 (main) and 2.77 ± 0.30 (control) ($p > 0.05$). The proportion of children with caries-causing plaque averaged 27.7 ± 8.4% (main) and 26.3 ± 8.8% (control). Over six months there were small, non-significant improvements in GI and plaque indices in both groups. After one year the main group demonstrated a statistically significant reduction in GI to 2.35 ± 0.11 ($p < 0.001$ versus baseline); the control group returned to baseline GI values (2.56 ± 0.13). At 1.5 years the main group continued to improve (GI 1.98 ± 0.12) while the control group showed minimal change (GI 2.55 ± 0.21); between-group differences were significant ($p < 0.01$). At two years the main group achieved a satisfactory hygienic state (GI 1.74 ± 0.16) with statistically significant differences versus the control group (GI 2.30 ± 0.19; $p < 0.001$). By 2.5 years the main group's mean GI decrease over the study period was 1.09 points (to GI 1.74 ± 0.10) and the proportion of children with caries-inducing plaque fell to 9.1 ± 5.0%; the control group retained a predominantly unsatisfactory status (final plaque proportion 21.2 ± 7.2%) with non-significant changes from baseline ($p > 0.05$).

3.7 Enamel remineralization and solubility dynamics

Baseline assessment of enamel remineralization after artificial demineralization in the main group showed an average recovery time of 4.30 ± 0.36 days; 45.4% of children completed remineralization within 2–3 days and 39.4% required ≥5 days. Initial enamel solubility in the demineralizing solution averaged 63.3%, indicating low acid resistance. The control group had a baseline mean remineralization time of 3.52 ± 0.35 days and enamel solubility 50.4%.

During follow-up, the intervention group exhibited progressive improvement in remineralization kinetics: mean recovery time decreased from 4.30 ± 0.36 days at baseline to 3.52 ± 0.28 days at 1 year, and to 2.09 ± 0.18 days by the end of year two ($p < 0.001$ versus baseline), remaining stable thereafter (≈2.12 ± 0.19 days). By year three, 87.8% of children in the main group remineralized within 2–3 days and only 3.3% required >5 days. Enamel solubility in the main group decreased from 63.3% at baseline to 30.9% at two years (a >50% reduction; $p < 0.05$), with a minor rise to 34.8% thereafter. In the control group, remineralization times and enamel solubility showed no sustained improvement and in some intervals trended toward increased solubility (final solubility ≈54.4%).

4. DISCUSSION

Screening of 740 schoolchildren in three rural communities of the Uzgen district revealed a high burden of dental caries and extensive rehabilitation needs, particularly during the mixed-dentition period. Concurrent water analyses demonstrated fluoride concentrations well below commonly accepted optimal levels. In the prospective pilot, implementation of a comprehensive prevention program that included endogenous administration of Kara-Shoro mineral water (130 mL/day), together with health education, therapeutic treatment and professional hygiene, produced substantial improvements in caries intensity, oral hygiene scores, plaque cariesogenicity and enamel remineralization indices compared with the contemporaneous control group.

4.1 Interpretation and mechanistic considerations

The observed reductions in caries intensity and enamel solubility, and the acceleration of remineralization kinetics in the intervention group, are consistent with a biologically plausible effect of increased ionic fluoride exposure [9]. Fluoride in bioavailable ionic form enhances enamel resistance to acid challenge, promotes remineralization and exerts antibacterial actions that reduce plaque cariogenicity [10]. The concurrent improvement in hygiene indices likely amplified preventive effects, while the mineral composition of Kara-Shoro (bicarbonate–chloride–sodium matrix with multiple microcomponents) may contribute complementary systemic and local benefits [11].

4.2 Public health implications

The combination of low environmental fluoride levels and high caries prevalence in the surveyed communities underlines a clear need for population-level preventive action [12]. The data support inclusion of fluoride-rich natural mineral water as one component of an integrated, school-based caries prevention strategy where water fluoridation is not feasible [13]. The program's multi-component design (education, therapeutic care, professional hygiene, and endogenous fluoride administration) appears effective in improving oral health outcomes over a multi-year horizon [14].

4.3 Strengths and limitations

Strengths include large baseline screening (n = 740) and longitudinal follow-up of a prospectively treated cohort with multiple clinical and laboratory end points (caries indices, hygiene indices, enamel remineralization and solubility tests). Limitations inherent to the presented data include reliance on a single geographic region, potential confounding from concurrent oral-hygiene interventions and parental supervision differences, and the absence of blinded allocation. Reported analyses used standard indices and produced statistically significant between-group differences for key outcomes .

5. CONCLUSIONS

A survey of 740 schoolchildren indicated that 77.9% needed rehabilitation, while 22.1% had previously completed the therapy. This study focused on the population of On-besh zhash, Ak-Terek, and Salamalik villages in Osh oblast's Uzgen District. The investigation revealed that the concentration of fluorides in the water supply ranged between 0.216 mg/l and 0.287 mg/l, which was 2-3 times lower than the stipulated sanitary requirements. The study determined that the Kara-Shoro mineral spring, located in the Uzgen district of the Osh region of the Kyrgyz Republic, belongs to the category of medium-mineralized carbon dioxide (6-8 g/dm3) waters with a weakly acidic reaction (pH 6.23), a high concentration of dissolved salts (up to 40 g/l), and a pronounced ferrous component. Water is characterized chemically as sodium bicarbonate-chloride, ferruginous medicinal table water, which has a protecting and remineralizing action, as well as a wide range of therapeutic applications. As a result of the research, the method of endogenous use of mineral water "Kara-Shoro" as an effective means of primary prevention of dental caries in children, providing an increased supply of fluorides and stimulating the remineralization of hard enamel tissues, was validated and implemented. The identified anti-inflammatory and barrier qualities of this water explain its use in the primary prevention of inflammatory illnesses of the oral cavity, as well as its role as an effective dental preventative agent. It has been demonstrated that the regular use of Kara-Shoro mineral water in the comprehensive prevention of caries in children resulted in a consistent improvement in key dental parameters: over three years, the hygiene index decreased significantly, the cariesogenicity of plaque decreased threefold, the caries resistance of enamel increased 1.5fold, and the remineralizing ability of oral fluid doubled. The results confirm the remarkable efficacy of endogenous fluoridation with this water in strengthening the hard tissues of teeth and lowering the risk of caries.

Acknowledgement: The authors would like to express their sincere gratitude to Osh State University for providing the research infrastructure and institutional support essential for the successful completion of this project.

Data availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical statement: The study protocol was reviewed and approved by the **Ethical Committee of Osh State University.** All procedures were conducted in accordance with the ethical standards of the institutional research committee and the principles outlined in the **Declaration of Helsinki**. Written informed consent was obtained from all participants prior to their inclusion in the study. The **corresponding author** can be contacted for further information regarding the study protocol, ethical approval, and data availability.

Funding: This research did not receive any specific funding.

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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