Assessment of Calcium, Magnesium, and Fluoride in Bottled and Natural Drinking Water from Jazan Province of Saudi Arabia and a Brief Review on Their Role in Tooth Remineralization

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Abstract:
Background: The minerals in the drinking water play a critical role in tooth remineralization apart from their systemic effects. This study estimated the quantity of calcium (Ca), magnesium (Mg), and fluoride (F) of commercially available bottled waters and natural drinking water in Jazan and compared them with their labeled values. The role of these minerals on tooth remineralization is briefly reviewed.

Materials and Methods: The concentration of Ca, Mg, and F was determined for 12 local brands and 6 imported brands of bottled water along with 8 sources of natural drinking water. Their concentrations were determined on the basis of analytical ion chromatography using a Dionex ICS 5000 ion chromatography system at the Food and Drug Authority laboratory, Saudi Arabia.

Result: The mean Ca concentration in local brands of bottled water (11.4 ± 9.8) is significantly less compared to imported brands (51.7 ± 18.7) and natural water (47.4 ± 58.5) and also below the optimum level (40-80 mg/dl). Similarly, the level of Mg is also lower in local brands (4.6 ± 5.6), but their differences with regard to imported brands (15.1 ± 14.6) and natural source (16.7 ± 27.1) are not statistically significant. The F content in local brand (0.9 ± 0.1) is in the optimum range (0.5-1.0 mg/dl) higher than imported brands (0.4 ± 0.6) and natural sources (0.3 ± 0.4). There is no significant difference between the labeled and estimated Ca, Mg, and F levels among the local and imported brands.

Conclusion: The local bottled water has suboptimal Ca and Mg with optimal F content. Although the imported bottled water and natural water have sufficient Ca and Mg, their F concentration is very minimal. Drinking water with an optimum level of Ca, Mg, and F provides a favorable environment to enhance the regeneration processes of the mineralized tissue in tooth cavious process. Knowledge of the mineral content of the drinking water and their health significance is essential to both public and health-care professionals.

Key Words: Bottled water, calcium and magnesium, drinking water, fluoride, Jazan

Introduction
Water is the elixir of life. Purity and mineral content of the drinking water are very important for human consumption. In recent years, people have resorted to bottled water compared to community water supplies in various countries, including Saudi Arabia. This is mainly due to apprehension about contaminants in natural water supplies.¹ Sales of bottled water have escalated, further leading to availability of innumerable brands of bottled water in Saudi Arabia. Although the quality of bottled water depends on their labeled mineral content,² most people do not pay enough attention to this. The minerals in the drinking water play a key role in human nutrition.³ The availability of ionic form of minerals in the drinking water enables them to be absorbed easily by the gastrointestinal tract.⁴ Apart from their systemic effects, the chemical components of drinking water affect the mineralized tissue of the oral cavity. This occurs either by systemic impact of calcium (Ca), magnesium (Mg), and fluoride (F) homeostasis which is indicated by their concentration secreted in saliva or through the local effect of minerals in drinking water on the teeth.⁵

Among all the mineral components in the drinking water, extensive research has been conducted on F and its influence on the mineralized tissue of teeth.⁶-¹⁰ Several studies have also assessed the quality of bottled water in Saudi Arabia.²,¹¹-¹⁶ The F content in this water is of great concern to the dentist due to its effects on dental caries. Knowledge about the health implications of minerals such as Ca and Mg on teeth is limited. It is believed that these minerals in drinking water also influence dental caries by enhancing the uptake of F in the oral biofilm. Studies concerning the effects of Ca and Mg on the resistance and susceptibility of teeth to demineralization are limited.⁵,⁷

Previous researches have proved that increased Ca in drinking water has reduced the DMF-S index.¹⁷-¹⁹ Another study by Bruno et al. showed that Ca and F together caused 45%
reduction in the number of DMF-S, supporting the role of Ca in tooth remineralization. The purpose of this study is to determine the quantity of Ca, Mg, and F of commercially available local and international brands of bottled drinking water and also in the natural drinking water available in Jazan Province. It also compares the estimated values with those printed on their labels and further reviews the effect of these minerals on tooth remineralization.

**Materials and Methods**

A total of 12 brands of local bottled water and six brands of imported bottled water were purchased randomly from different supermarkets of Jazan. Eight samples of drinking water were obtained from natural sources in different areas of Jazan Province, Saudi Arabia. All the bottled waters were valid for 1 year from their production date as indicated on their label. Almost all the bottled water brands have mentioned their mineral content on their label. The water samples were stored in closed plastic containers with tight plastic screws at room temperature until the analysis was made. 100 ml sample was taken and kept in a sterile container. Each sample was assigned a code to avoid bias. The concentration of Ca, Mg, and F was determined on the basis of analytical ion chromatography using a Dionex ICS 5000 ion chromatography system. All the measurements were made at the Riyadh Food control Laboratory, Food and Drug Authority, Saudi Arabia. A statistical comparison was carried out between the sample groups using Kruskal–Wallis test (SPSS version 17) taking P ≤ 0.05 as the level of significance. Comparison of labeled and estimated values of Ca, Mg, and F among the local and imported brands of bottled water was carried out using Wilcoxon signed ranks test. Intergroup comparison of Ca, Mg, and F among the sample group was done with Mann–Whitney test.

**Results**

The drinking water quality standards in Saudi Arabia are issued by Saudi Arabian Standards Organization (SASO). According to SASO, the acceptable range of Ca is 200 mg/l; Mg 30-150 mg/dl, and F 0.6-1.0 mg/l. However, the optimum level of Ca, Mg, and F levels in drinking water for systemic health is 40-80, 20-30, and 0.5-1.0 mg/l, respectively. The minerals in the drinking water form a major dietary source of Ca and Mg. They play an important role in the physiological functions of the body. The positive effect of F on human health is its anticariogenic property. The optimum Ca and Mg levels in drinking water for systemic health should be 40-80 and 20-30 mg/l, respectively. According to Lagocka et al., the concentration of Ca in saliva to enhance the repair of initial carious lesion should not be <40 mgCa/dm³ and >90 mgCa/dm³. The optimal concentration of F for dental health is generally between 0.5 and 1.0 mg/l.

The integrity of tooth enamel is determined by the chemical composition of saliva and dental plaque. This is subject to

<table>
<thead>
<tr>
<th>Water minerals</th>
<th>Local brand</th>
<th>Imported brand</th>
<th>Natural source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>11.4±9.8</td>
<td>51.7±18.7</td>
<td>47.4±58.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4.6±5.6</td>
<td>15.1±14.6</td>
<td>16.7±27.1</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.9±0.1</td>
<td>0.4±0.6</td>
<td>0.3±0.4</td>
</tr>
</tbody>
</table>

*P<0.05. Ca: Calcium, Mg: Magnesium, F: Fluoride, SD: Standard deviation

**Discussion**

This was the first study which estimated the level of Ca, Mg, and F levels in drinking water samples in Jazan, South Western region of Saudi Arabia. Although studies based on F level in the bottled waters and natural water was carried out earlier.

The minerals in the drinking water form a major dietary source of Ca and Mg. They play an important role in the physiological functions of the body. The positive effect of F on human health is its anticariogenic property. The optimum Ca and Mg levels in drinking water for systemic health should be 40-80 and 20-30 mg/l, respectively. According to Lagocka et al., the concentration of Ca in saliva to enhance the repair of initial carious lesion should not be <40 mgCa/dm³ and >90 mgCa/dm³. The optimal concentration of F for dental health is generally between 0.5 and 1.0 mg/l.

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**Table 1: Mean comparison of Ca, Mg, and F in drinking water samples from local brands, imported brands, and natural source using Kruskal–Wallis test.**

<table>
<thead>
<tr>
<th>Drinking water samples</th>
<th>Ca</th>
<th>Mg</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local brand: Imported brand</td>
<td>0.000*</td>
<td>0.005*</td>
<td>0.013*</td>
</tr>
<tr>
<td>Local brand: Natural source</td>
<td>0.007*</td>
<td>0.384</td>
<td>0.000*</td>
</tr>
<tr>
<td>Imported brand: Natural source</td>
<td>0.3451</td>
<td>0.491</td>
<td>0.414</td>
</tr>
</tbody>
</table>

*P<0.05. Ca: Calcium, Mg: Magnesium, F: Fluoride

**Table 2: Intergroup comparison of Ca, Mg, and F among the sample group by Mann–Whitney test.**

<table>
<thead>
<tr>
<th>Drinking water samples</th>
<th>Ca</th>
<th>Mg</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local brand: Imported brand</td>
<td>0.000*</td>
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consistent change by demineralization and remineralization process. In dental carious process, the acids produced from the fermentation of carbohydrates by acidogenic bacteria alter the pH of the oral biofilm leading to demineralization of teeth. Saliva plays a critical role in the prevention of tooth demineralization and initiation of remineralization. Salivary buffers neutralize the acids and further enhance the diffusion of Ca, Mg, and F, thereby promoting remineralization. Saliva and dental plaque have Ca and phosphate (Pi) in supersaturated concentrations with respect to the tooth mineral. These ions are continually deposited on the enamel surface or redeposited in demineralized area. It is a natural defense mechanism to preserve the integrity of tooth on exposure to acids.

The hydroxyapatite (HA) crystals in tooth enamel, made up of Ca, Mg, and Pi is more susceptible to dissolution by acids. If the pH is not <4.5, lost HA is immediately replaced by fluorapatite in the presence of F in the oral biofilm which is less susceptible to acid dissolution. This process leads to a decrease in demineralization and not considered as remineralization because a different mineral is redeposited. Besides reduction of enamel demineralization, F also enhances remineralization when the pH rises. Ca may augment this process by providing extra binding sites for F. While the role of Mg in teeth remineralization process is by modifying the enzymatic activity of alkaline phosphatase which helps in formation of HA crystals. It also promotes the growth of HA crystals and stabilizes the amorphous form of Ca Pi. It should be emphasized that saliva is the main source of minerals that rebuild demineralized enamel.

In this study, the local bottled water have a lower concentration of Ca and Mg than recommended, which is insufficient to promote tooth remineralization but rather adequate amount of F is present to exert their anticariogenic action. The imported bottled water has maintained optimal Ca, whereas their Mg and F levels are comparatively lower. The natural source of drinking water had quite a good amount of Ca and Mg compared to the local bottled water; however, their F level is negligible. Considering the implication of these minerals in systemic and dental health, it is imperative for the manufacturers to maintain recommended amount of these minerals in their water products. The recommended dietary allowance of Ca and Mg for adults is 800 mg and 350 mg per day, respectively. Since the bioavailability of these minerals in water is higher compared to their dietary source, selecting bottled water with high mineral content may help to achieve the daily recommended intake. Moreover, it is proved that cooking food with soft water markedly reduces the content of Mg and Ca in food up to 60%. In contrast, hard water causes minimal loss of these elements during cooking or may even fortify the Ca content.

F is an essential element for healthy teeth and thus added to the drinking water to avoid caries. F concentrations in the studied water samples vary between 0.61 and 1.07 mg/L with an average value of 0.9 mg/L for local bottled water. The imported bottled waters had a wide range from 0 to 1.05 with a mean of 0.4 mg/L which is below the recommended levels. In Saudi Arabia, few reports have been published earlier about the F content of local and imported bottled water. Review of previous studies showed similar results with most samples of imported bottled water exhibiting a lower than recommended amount of F, whereas majority of local bottled water maintains an ideal concentration of F. Negative and positive types of variations were noticed in the levels of Ca, Mg, and F as compared to the labeled values in both local and imported bottled water. However, their difference is statistically insignificant. This variation may be due to the fact that most bottled water manufacturers print their labels in bulk and later use them to label their products without verifying the actual concentration of these minerals in the water stored in the bottles. It, therefore, requires more stringent control from the bottled water regulatory agencies.

The prevalence of dental caries is quite high in this population. A population-based study among the children of Saudi Arabia showed that 80% of their primary dentition and approximately 70% of permanent dentition are affected by caries. This warrants the immediate attention of the health officials in Saudi Arabia and requires considerable preventive strategies. Several studies have shown that increased Ca, Mg, and F in the drinking water leads to low caries experience. As part of preventive measures against dental caries, the manufacturers of bottled water may consider providing waters with optimum mineral compositions which are beneficial for both systemic and dental health of the public. Furthermore, the general public and health professionals should be aware of the composition of their drinking water.

Conclusion

The mineral content of both commercially available bottled Water and natural drinking water showed variation with suboptimal level of Ca and Mg in local bottled water. Although the imported bottled water and natural water have sufficient Ca and Mg, their F concentration is below the optimum. As minerals in drinking water may provide substantial contribution to total intake of these nutrients, the manufacturers should ensure the quality of bottled water by supplementing it with the recommended quantity of these minerals. Drinking water with the recommended concentration of Ca, Mg, and F creates a positive milieu in the oral cavity for promoting remineralization processes in mineralized tissue. Knowledge of the mineral content of the drinking water and their health significance is essential to both public and health-care professionals. Planning of preventive dental programs and prescription of Ca, Mg, and F supplements depends on the intake habits by the population. Further studies correlating the levels of these minerals in
drinking water and the prevalence of dental caries in this geographic region are recommended.

Acknowledgments

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References