Effects of xylitol chewing gum on salivary flow rate, pH, buffering capacity and presence of Streptococcus mutans in saliva

ABSTRACT

Aim The first studies on the use of chewing gum in dentistry were done in the 1970s. The Turku Sugar Studies, carried out between 1970 and 1973, showed the excellent anticaries properties of xylitol chewing gums. Since then, many dentists, particularly in Scandinavian countries, have studied the role of chewing xylitol-sweetened chewing gums as another preventive strategy in the control of dental caries. Objective: To compare variations in salivary flow rate, pH, buffering capacity, and levels of Streptococcus mutans in baseline conditions and after chewing paraffin pellets or xylitol chewing gum in children between the ages of 6 and 12 years who eat lunch in a school canteen. Materials and methods The study sample consisted of 90 children divided into 2 study groups, and a control group. The children ate lunch at the canteen of the Escultor Ortells state school in the town of Vila-real (Castellón, Spain). The baseline data recorded in the first phase of the study were compared with the data recorded in the second phase, after 15 minutes of chewing xylitol-sweetened chewing gums or paraffin pellets, depending on the study group. Salivary flow rate was measured by collecting the stimulated saliva in a graduated beaker. Levels of pH were measured using a Cyberscan pH 110 pH meter (Eutech Instruments®). CRT® buffer strips and the CRT® bacteria test (Ivoclar-Vivadent) were used to measure buffering capacity and levels of S. mutans, respectively. Results The data obtained after sample collection were compared by means of a 1-way analysis of variance using the Statgraphics Plus statistical software package, version 5.0. Statistically significant differences were found (p <0.05) when pH, buffering capacity and levels of S. mutans were compared between the 3 groups. Comparison of salivary flow rates revealed no statistically significant differences (p >0.05), though salivary flow rates were higher in the groups where gum was chewed. Conclusions The effect of chewing is essential to the stimulation of salivary flow and the resulting recovery of pH levels and reduction of levels of S. mutans in saliva.

Key words: Caries; Prevention; Saliva; Chewing gum; Xylitol.

Introduction

The fall in the incidence of dental caries is not accidental, but is due to the correct application of suitable preventive measures. The prevalence of dental caries in developed countries has fallen markedly over the last 10 years, particularly in the United States and Scandinavian countries. The lower prevalence of this disease in countries of the European Union is the result of a motivational plan by dentists, parents and educators that has the main aim of encouraging children to acquire appropriate dietary and hygiene habits. The incidence of dental caries also fell in Spain from the 1990s onward, though on a smaller scale [Barasona, 2000; Bravo et al., 2005] as shown by the last survey carried out by the General Council of Spanish Associations of Dentists (Ilustre Consejo General de Colegios de Odontólogos y Estomatólogos de España). This survey was carried out in 2005 and shows a lower incidence of caries [Seki and Yamashita, 2005]. This reduction is due to schoolchildren’s compliance with different preventive strategies: correct management of dental plaque, fluoridation and increasing use of chewing gum [Ramon and Montserrat, 2000].

The first studies on the use of chewing gum in dentistry were done in the 1970s. The Turku Sugar Studies, carried out between 1970 and 1973, showed the excellent anticaries properties of xylitol chewing gum [Scheinin et al., 1975; Honkala et al., 1999]. Since then, many dentists, particularly in Scandinavian countries, have studied the effect of chewing xylitol-sweetened chewing gum as another preventive strategy in the control of dental caries [Scheinin et al., 1975]. A literature research in Spain revealed no published studies on the effect of xylitol chewing gum on salivary flow rate, pH, buffering capacity or levels of Streptococcus mutans in saliva in children who chewed this type of chewing gum.

We became aware of this situation following a survey carried out in all the schools in the town of Vila-real (Castellón, Spain). The objective of the survey was to examine the opportunities for brushing teeth available to children who ate lunch in the school canteen. Of the 15 schools surveyed, only 3 provided pupils with the opportunity to brush their teeth. The main reasons given by the other 12 schools for not allowing pupils to brush their teeth were the lack of suitable facilities and the lack of staff to supervise correct brushing.

Several studies in the area of dental-caries prevention have shown that chewing xylitol-sweetened chewing gum may constitute another preventive strategy in daily oral hygiene [Aguirre-Zero et al., 1993; Trahan, 1995; Autio and Corts, 2001; Holgerson et al., 2005]. Chewing xylitol-sweetened chewing gum can therefore be recommended in schools as a substitute for brushing teeth after lunch in situations where the facilities are unsuitable and there is a lack of available staff to supervise correct brushing.

The findings of those studies were the main reason for this trial, which aimed to show that chewing xylitol-sweetened chewing gum could be included as a preventive strategy in schools [Twetman and Stecksen-Blicks, 2003; Peng B et al., 2004]. Different authors currently disagree on whether the prevention of caries produced by chewing gum is due mainly to the effect of chewing, which increases salivary flow rate,
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or to the chemical composition of the sweetener, in this case xylitol [Maaning et al., 1992; Söderling et al., 1997; Autio and Corts, 2001; Dawes and Kubieniec, 2004; Askoy et al., 2005]. We therefore decided to compare the effect of chewing xylitol-sweetened chewing gum with the effect of chewing paraffin pellets and of not chewing in a cross-sectional trial involving a single episode of chewing paraffin pellets or chewing gums.

After establishing the justification for carrying out this trial, we considered the main objective to be to evaluate the salivary flow rate, pH, buffering capacity, and levels of S. mutans in children from 1 school after eating carbohydrates and then chewing xylitol-sweetened chewing gums or paraffin pellets, or not chewing.

Materials and methods

A cross-sectional clinical trial was carried out in 2007 to evaluate the effect of xylitol chewing gum on salivary flow rate, pH, buffering capacity and levels of Streptococcus mutans in saliva in a group of primary school students. The trial included 90 children (47 boys and 43 girls) between the ages of 6 and 12 years from the Escultor Ortells state school in the town of Vila-real (Castellón, Spain), who ate lunch at the school canteen.

When approval had been obtained from the school authorities, a letter was sent by the principal researcher to the children’s parents. The letter provided information in easy-to-understand language in order to obtain the written informed consent of the parents. The parents were informed of the nature of the trial, which was carried out by appropriately qualified students in the Master’s Programme on Comprehensive Paediatric Dentistry at the Universitat Internacional de Catalunya (UIC), in compliance with current regulations on research on humans. The trial protocol had been approved by the Ethical Research Committee of the UIC Faculty of Dentistry.

The following factors were established when selecting subjects.

- Inclusion factors: children between the ages of 6 and 12 years who ate lunch at the canteen of Escultor Ortells state school in Vila-real and who volunteered to take part in the trial after the signed informed consent form had been received from their parents.
- Exclusion factors: children younger than 6 years of age and older than 12 years of age, children taking medication linked to alterations to saliva, children with orthodontic appliances, children with psychological disorders, motor disorders and/or unidentified syndromes.

The study sample was divided randomly into 2 study groups and a control group. Each group was assigned a colour (red, green or blue) and was made up of 30 children of both sexes and different ages between 6 and 12 years who were identified by a number and the colour of the group to which they belonged (Fig. 1).

Samples were collected by the principal researcher with the help of 4 appropriately qualified researchers from the Master’s Programme in Comprehensive Paediatric Dentistry at the UIC. The students of each group were taken to a room equipped for the purpose, where they sat in groups of 6 in order to provide the samples. One person was responsible for monitoring sample collection. The following items were set out on the table and were labelled with the colour of the group to which each subject belonged (red, green or blue), and the corresponding number that identified each child:

- two graduated beakers for measuring salivary flow rate in baseline conditions and after chewing or not chewing;
- two CRT buffer strips for measuring buffering capacity in baseline conditions and after chewing or not chewing, together with 2 pipettes for collecting the saliva from the graduated beaker and performing the test;
- a subject identification sheet for recording the salivary flow rate and buffering capacity.

When the children had sat down, the person in charge of each table instructed the children in simple language to spit, while chewing a paraffin pellet for 5 minutes, into the beaker in order to measure the stimulated salivary flow rate in baseline conditions (Fig. 2A). Saliva was then taken...
from the beaker using a pipette to perform the CRT®
buffer test (Fig. 2B) to determine the buffering capacity by
means of a system of special indicators.

After the subjects had eaten a portion of carbohydrates,
they drank a small glass of water and then chewed either
xylitol chewing gum or paraffin pellets. When the amount
of stimulated saliva was studied, it was decided that the
control group, which was not initially meant to chew
anything, should chew paraffin pellets for a period of 3
minutes, which was enough time to collect a sample of
stimulated saliva. In the 15 minutes after eating, while the
children chewed, they received information on oral
hygiene by means of a video, courtesy of Colgate®, used
for school prevention campaigns. After 15 minutes, the
children were once again asked to spit into the second
beaker and the researcher responsible repeated the
measurement of salivary flow rate and the CRT® buffer
test; the results were also recorded on the identification
sheet.

After the salivary flow rate and buffering capacity had
been recorded, the beakers were taken to an auxiliary
table where the pH of the saliva samples was measured
using a portable pH meter (Cyberscan pH 110, Eutech
Instruments®) (Fig. 2C). The CRT® bacteria test was then
performed to determine levels of S. mutans (Fig. 2D). This
bacteria test was developed to determine the number of
bacteria (in this case S. mutans) in plaque and saliva and
uses a selective substrate by placing NaHCO3 in the
bottom of the vial to inhibit the growth of other bacteria
also present in saliva. The vials were then incubated for 48
hours at 37°C. After 48 hours of incubation, the vials were
removed from the incubator and an approximate count of
the colony-forming units (CFU) of S. mutans was
performed.

Figure 3 details the steps taken to collect the samples.

Results

After the results were obtained, we performed a
statistical analysis of the data using a 1-way analysis of
variance with the aid of the StatGraphics Plus statistical
software package, version 5.0. A detailed explanation of
the variations in each of the 4 parameters studied in the
trial, in baseline conditions and after chewing paraffin
pellets or chewing gum is reported in Table 1.

Salivary flow rate

Comparison of salivary flow rate in baseline conditions
and after chewing xylitol-sweetened chewing gum or
paraffin pellets, or not chewing (control group) revealed
no statistically significant differences between the 3
groups (p > .05) for a significance level of 95%, though
salivary flow rates were higher in the groups where gum
was chewed (Table 1).

Saliva pH

Comparison of pH in baseline conditions and after
chewing xylitol-sweetened chewing gum or paraffin
pellets, or not chewing (control group) showed statistically
significant differences (p < .05) (Table 1).

Buffering capacity

Comparison of buffering capacity in baseline conditions
and after chewing xylitol-sweetened chewing gum or
paraffin pellets, or not chewing (control group) showed
statistically significant differences (p = .0034) (Table 1).

Levels of S. mutans in saliva

Comparison of levels of S. mutans in baseline conditions
and after chewing xylitol-sweetened chewing gum or
paraffin pellets, or not chewing (control group) showed
statistically significant differences (p = .0058) (Table 1).

Comparison of the last 3 parameters showed a p value
of < .05, indicating statistically significant differences
between the 3 groups for a significance level of 95%.

Discussion

The development of sugar-free chewing gum provided
an alternative to chewing gum sweetened with sugar,
which, according to different authors, led to a slight drop
in plaque pH. Chewing gum containing non-cariogenic sweeteners after eating carbohydrates causes the pH to rise due to the stimulation of salivary flow, with a resulting increase in bicarbonate levels [Edgar, 1998], this leads to a reduction, in the long term, in the incidence of caries [Scheinin et al., 1975].

A review of the literature shows that chewing gum containing xylitol produces the best results in terms of the parameters studied in this trial [Honkala et al., 1999; Ramon and Montserrat, 2000; Auto, 2002; Dawes and Kubieniec, 2004; Askoy et al., 2005]. We therefore established 2 study groups consisting of children who chewed xylitol-sweetened chewing gums and children who chewed paraffin pellets. The control group chewed paraffin pellets for a shorter period of time to allow us to observe possible differences in the effect of chewing on our study variables. While the literature contains some cases of in vivo studies that use chewing of a placebo such as paraffin, most studies compare different sweeteners [Koparal et al., 2000; Auto and Courts, 2001].

Different authors find that chewing xylitol-sweetened chewing gum increases salivary flow rate, pH, and buffering capacity, and reduces levels of S. mutans in saliva. They attribute these effects to the chemical properties of xylitol. Other authors, however, find that the effect of chewing is essential and state that these effects are due more to the act of chewing than to the chemical composition of xylitol [Tanzer et al., 1995; Trahan, 1995; Söderling et al., 1997; Alen et al., 2000].

No statistically significant differences were observed between salivary flow rate in baseline conditions and after chewing xylitol-sweetened chewing gum or paraffin pellets, or not chewing, though salivary flow rates were higher in the groups where gum was chewed. The salivary flow rate was higher in the group of children who chewed paraffin pellets than in the group of children who chewed xylitol-sweetened chewing gum or the control group. This effect may be due to the fact that paraffin stimulates increased chewing because of its hardness, resulting in an increased salivary flow rate [Auto and Corts, 2001; Auto, 2002].

All the data analysed of salivary flow in the paper correspond to stimulated saliva. An important factor which could be analysed are the unstimulated saliva data, initially measured in the three groups with the aim to value the existence of meaning statistical differences, when compare stimulated and unstimulated saliva. In this way we cannot see meaning statistical differences among the groups which chew and the one which does not. This fact shows that initially the values of baseline salivary flow would be different.

The findings of several authors agree with the results of our trial in that no statistically significant differences were observed between the 3 groups. Machiulskiene et al. found that the act of chewing is essential to increase salivary flow rate, which leads to the prevention of dental caries, independently of the sweetener contained in the chewing gum, though they considered that harder chewing gums tend to stimulate a higher salivary flow rate [Machiulskiene et al., 2001]. When comparing the effect of salivary stimulation and the resulting recovery in pH levels after chewing xylitol-sweetened chewing gum or natural gum (Pistacia lenticus), Koparal et al. [2000] found that both parameters increased to a greater extent in the group of children who chewed natural gum. Aguirre-Zero et al. [1993] studied the effect of chewing gum containing xylitol, sorbitol or saccharose, and of not chewing gum in different groups. They found no statistically significant differences between the study groups in terms of the increase in salivary flow rate and considered the effect of chewing to be an essential factor in the anticaries effect of chewing gum. Tanzer et al. [1995] found no evidence to support the hypothesis that chewing a xylitol-sweetened chewing gum increases salivary flow rate, as no statistically significant differences were found between chewing gums containing different sweeteners.

A brief examination of the literature, however, shows that there are many studies, such as the one by Masalin, reporting that chewing xylitol-sweetened chewing gum produces a considerable increase in salivary flow rate; those studies highlight the importance of xylitol in preventing dental caries due to the increase in stimulated saliva [Masalin K, 1992]. Similarly, Bin Peng et al. state that the most notable effects of the use of sugar-free chewing gum include its ability to increase salivary flow rate and points out that xylitol-sweetened chewing gums significantly reduce the incidence of caries due to the potential effect of increased salivary flow [Peng et al., 2004].

Following our trial, we believe that, due to the increased salivary flow rate [Askoy et al., 2005], the act of chewing is a more essential factor in the anticaries effect of chewing gum than the sweetener (in this case, xylitol) of the chewing gum. Chewing paraffin and chewing gum stimulates salivary flow, leading to an increase in pH and buffering capacity and facilitating remineralisation, thus preventing the development of dental caries.

Comparison of pH in baseline conditions and after chewing xylitol-sweetened chewing gum or paraffin pellets, or not chewing (control group) showed statistically significant differences. The subjects who chewed xylitol-sweetened chewing gum or paraffin pellets showed greater recovery of pH levels after chewing than the control group. We understand that the increase in pH in both groups is mainly due to the effect of chewing. While this increase was slightly higher in the group that chewed chewing gum, the increase in salivary flow was not directly proportional to the increase in pH. Dawes and Kubieniec showed that prolonged chewing of gum (up to 120 minutes) led to an increase in pH due to the increase in stimulated saliva [Dawes and Kubieniec, 2004]. In that article, the authors cited a similar study carried out by Polland et al., in which analysis of stimulated saliva showed a less significant recovery of pH levels than in their study. Dawes and Kubieniec justified this difference by the size of the chewing gum in the study by Polland et al. (1.5 g), which was smaller than theirs (2.0 g). The study by Manning and Edgar found no statistically significant differences in pH recovery after eating meals or snacks followed by chewing for 20 minutes using chewing gum sweetened with sugar or other sweeteners [Manning and Edgar, 1993]. Park et al. [1991], however, found that chewing sugar-free chewing gum for 20 minutes was more effective in producing recovery of pH levels.
Other authors consider that chewing gums sweetened with sugar substitutes, such as polyalcohols, leads to recovery of pH levels after eating carbohydrates and the successful control of caries, depending on the type of sweetener. Grillaud et al. showed that chewing xylitol-sweetened chewing gums led to greater recovery of pH levels [Grillaud et al., 2005]. A review by Ramon andMontserrat [2000] of the literature on the effects of chewing xylitol-sweetened chewing gum found that recovery of pH levels was greater in subjects who chewed xylitol chewing gum.

We therefore understand that the act of chewing is essential to increase pH levels after chewing paraffin pellets or chewing gums, independently of the presence of xylitol in the gum.

Comparison of buffering capacity in baseline conditions and after chewing xylitol-sweetened chewing gums or paraffin pellets, or not chewing showed statistically significant differences. The ability to buffer against acid was greater in the 2 study groups, and the pH value was higher.

Because the reviewed literature contains few studies that analyse buffering capacity, our discussion on this point is limited and focuses primarily on the results of our trial. Firstly, Machiulskiene et al. determined that buffering capacity can be increased with the use of larger pieces of chewing gum, which encourage chewing and hence the buffering effect of the raised pH [Machiulskiene et al., 2001]. As in our study, Burt found that chewing any type of chewing gum led to increased buffering capacity due to the stimulation of salivary flow, which resulted in neutralisation of the plaque pH. This anticaries benefit was due to chewing, independently of the sweetener contained in the chewing gum [Burt, 2006].

As mentioned above, however, the review by Ramon and Montserrat [2000] also showed that chewing xylitol-sweetened chewing gum produces a greater buffering capacity in the saliva. We therefore feel that the act of chewing is essential to increase buffering capacity after chewing paraffin pellets or chewing gums, independently of the presence of xylitol in the gum.

Comparison of levels of S. mutans in saliva in baseline conditions and after chewing xylitol-sweetened chewing gum or paraffin pellet, or not chewing (control group) showed statistically significant differences. The control group showed the highest levels of S. mutans in saliva and this was mainly linked to the reduced stimulation of salivary flow.

Xylitol inhibits the development of S. mutans and reduces the formation of dental plaque [Park et al., 1991]. This antibacterial property is essentially due to the fact that glucose is replaced by xylitol. S. mutans requires high concentrations of xylitol in order to obtain a similar growth to that observed when glucose is metabolised [Tanzler, 1995].

Studies such as the one by Aksoy et al. [2005] show that chewing gum containing natural products with antibacterial and antimicrobial properties, such as P lentiscus, derived from trees found in the Mediterranean region (Turkey), do not require sweeteners such as xylitol and sorbitol, and are sufficient to reduce levels of S. mutans in saliva [Aksoy et al., 2005]. That study compared the effect of chewing a placebo gum (mainly composed of paraffin) with a group of subjects who chewed a resin gum. Statistically significant differences were observed when the antimicrobial effect in the study group was compared with the control group. Similar results were obtained by Takahashi et al. in a study with a similar design published in 2003 [Takahashi et al., 2003].

Studies such as those carried out by Söderling et al. [1997], Isokangas et al. [1988], and Mäkinen et al. [2005] have shown that chewing a xylitol-sweetened chewing gum reduces the levels of S. mutans in saliva. Thus, after a 6-month study of a sample of 5-year-old children who chewed chewing gums sweetened with either xylitol or sorbitol, Mäkinen et al. found that the reduced levels of S. mutans were not due simply to the effect of chewing. The greatest reduction was caused by the antibacterial effect of xylitol. Similarly, Auto established that xylitol-sweetened chewing gum had an important antiteicaries effect due to the antibacterial properties of this type of sweetener, which produces a greater reduction in lactic acid. In most studies, however, this antibacterial effect is found only when chewing xylitol-sweetened chewing gum is analysed over a longer period of time [Auto, 2002].

While our study found that the group of children who chewed chewing gums had higher levels of S. mutans in comparison with the group who chewed paraffin pellets, there is insufficient evidence in the literature to support the hypothesis that chewing is essential to reduce levels of this microorganism. It is important to bear in mind that increased salivary flow rate increases the levels of antibacterial agents in the saliva and the 2 study groups therefore had lower levels of S. mutans in saliva. Nevertheless, the group that chewed xylitol-sweetened chewing gum would have lower levels of S. mutans after chewing 4 or 5 pieces of this type of chewing gum (equivalent to 5 g/day of xylitol) for a minimum of approximately 2 weeks.

Conclusions

- No statistically significant differences were found in the stimulation of the salivary flow rate between chewing xylitol-sweetened chewing gum and chewing paraffin pellets.
- Statistically significant differences were found between the study groups and the control group in terms of increased pH.
- Chewing xylitol-sweetened chewing gums produced greater recovery of pH levels than chewing paraffin pellets.
- Chewing paraffin pellets produced a greater reduction in levels of S. mutans in saliva than chewing xylitol-sweetened chewing gums.
- The effect of chewing was essential to stimulate salivary flow and the resulting recovery of pH levels and reduction of levels of S. mutans in saliva.

References

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