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Journal of Prosthodontic Research

journal homepage: www.elsevier.com/locate/jpor

Original article

Association between chewing-stimulated salivary flow under the effects of atropine and mixing ability assessed using a color-changeable chewing gum

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ARTICLE INFO

Article history:
Received 18 July 2016
Received in revised form
26 December 2016
Accepted 26 December 2016
Available online xxx

Keywords:
Atropine
Mouth dryness
Saliva
Chewing gum
Mastication

ABSTRACT

Purpose: To assess the time course of chewing-stimulated salivary flow after oral atropine administration, and determine the association between chewing-stimulated salivary flow and mixing ability using color-changeable chewing gum in dentate adults.

Methods: Ten healthy dentate adults were administered 1 mg oral atropine to induce mouth dryness. The subjects' chewing-stimulated salivary flow was assessed using the Saxon test. They were then asked to rinse their mouth with tap water for 15 s, and to chew on color-changeable chewing gum for 60 s at a constant rate of 60 cycles per min. This procedure was performed before, and at 10-min intervals for up to 120 min after the atropine administration. The experiment was repeated after 1 week. Steel's test was used to compare the chewing-stimulated salivary flow rates at each time point after atropine administration with the baseline value. The effect of the stimulated salivary flow rates on the degree of color change was analyzed using linear mixed effects models, with the stimulated salivary flow rates as fixed factors and subjects as the random factor.

Results: Chewing-stimulated salivary flow showed a significant decrease from 50 to 120 min after oral atropine administration ($P < 0.05$) and the amount of chewing-stimulated salivary flow had a significant effect on the color change of the color-changeable chewing gum ($P < 0.001$).

Conclusions: We observed a decrease in stimulated salivary flow after orally administering 1 mg atropine, and a positive association between mixing ability using color-changeable chewing gum and chewing-stimulated salivary flow in dentate subjects.

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http://dx.doi.org/10.1016/j.jpor.2016.12.009

1. Introduction

Saliva plays an important role in keeping the oral mucosa moist and preventing tooth decay [1]. Therefore, xerostomia results in several problems such as taste disorder, poor denture stability, difficulty in chewing hard foods, and difficulty in speech and articulation [2]. Furthermore, it increases the number of chewing strokes required before swallowing [3], increases the difficulty in chewing sticky foods [4], and decreases the intake of whole grains [5]. In previous studies using subjective self-assessments of the chewing ability of individuals, it was found that chewing difficulties depend on the food texture and hardness [4,5]. In the process of mastication, the major functions of saliva are to gradually reduce the spaces between particles, increase viscous cohesion, and promote bolus formation [6]. In subjects with low unstimulated salivary flow rate, adding fluid when chewing dried food can reduce the amount of masticatory muscle activity required [7].

Because salivary flow rate is considered to have an influence on masticatory ability, it is necessary to consider the relationship between them. To fully clarify this association, an objective and reliable method must be used, preferably one in which the measured variable has a direct association with salivary flow rate, and is readily apparent.

Although various objective methods have been developed, the most common methods are sieve methods using natural foods such as peanuts and almonds, and artificial tests using silicone-based test foods, which are recognized as gold standards [8]. However, the sieve method can be messy and time-consuming, especially in elderly and oral cancer patients, who need to undergo such assessments more frequently than do young, healthy, dentate individuals. Another objective method of measuring the mixing and kneading ability is the use of wax [9] or gum [10,11]. Gum is more popular than wax or other artificial test foods, because it allows the subject to chew easily and naturally, and can be easily removed from the oral cavity after the test is complete.

In recent years, color-changeable chewing gum has been widely used as an objective assessment of masticatory ability. Mixing ability, assessed using color-changeable chewing gum, is associated with physical ability [12] and sarcopenia [13] in elderly people. Furthermore, color-changeable chewing gums have been successfully used for the determination of masticatory efficiency in mandibulectomy and glossectomy patients [14–16], implying that it is suitable for use in a wide range of patients.

The color change of the gum can be judged using a handheld colorimeter [17] and color scale [18]. Due to the ease of administration and assessment, we believe that it is highly suitable for measuring individual masticatory ability.

The relationships between masticatory ability and multiple factors such as jaw movement [19], occlusal support zone [20], and lip and tongue function [21] have been assessed using color-changeable gum, but the impact of salivary flow rate has not been evaluated.

Liedberg and Owall [3] and Ishijima et al. [22] used drugs to induce dry mouth to exclude the influence of other factors involved in masticatory function except for saliva. In order to clarify the relationship between masticatory ability, as assessed using the color-changeable gum, and the amount of saliva, atropine sulfate is suitable for reducing the amount of saliva flow and assessing the effect of different amounts of saliva on masticatory ability. In contrast, previous studies have evaluated the time course of salivary flow changes under the effect of atropine in young adults; one measured acid-stimulated salivary flow rates after the intravenous administration of various atropine doses [23], and another measured unstimulated salivary flow rates after oral and intramuscular atropine administration [24]. However, no study has evaluated the time course of chewing-stimulated salivary flow rates after atropine administration. Investigating this relationship will provide useful information for conducting future experiments on masticatory performance requiring simulation of xerostomia conditions, using atropine.

Therefore, the aims of the present study were to: (1) assess the time course of changes in chewing-stimulated salivary flow after oral atropine administration, and (2) evaluate the relationship between the amount of chewing-stimulated salivary flow and mixing ability using color-changeable chewing gum in healthy dentate adults.

2. Materials and methods

The study protocols were independently reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Tokyo Medical and Dental University (#877) and conformed to the principles described in the Declaration of Helsinki (2002). The experiments were undertaken with the understanding and written consent of each subject.

2.1. *Participants*

We recruited 10 volunteers (five men and five women) aged 27–43 years for this study. Their mean body weight was 59.1 ±9.7 kg. Only healthy, dentate, and nonsmoking individuals were included. Individuals with temporomandibular joint disorders, smoking history, xerostomia, caries or periodontal disease, and missing teeth other than third molars were excluded. Furthermore, patients with contraindications for atropine use, such as glaucoma, urination disorder due to prostatic hypertrophy, paralytic ileus, congestive heart failure, serious heart disease, ulcerative colitis, sensitivity to atropine, and hyperthyroidism were excluded.

2.2. *Study design and protocol*

Participants were instructed not to eat, drink, or brush their teeth from at least 2 h before the experiment and to refrain from consuming alcoholic beverages from 12 h before the experiment. Participants were made to sit comfortably in a quiet room and were given oral and written information about the study procedures. The salivary flow rate was measured using the Saxon test [25] once before, and 12 times at 10-min intervals after the oral administration of 1 mg atropine. Following each Saxon test, all participants were instructed to rinse their oral cavities and instructed to chew on the color-changeable chewing gum for the mixing ability