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Development of a Colorimetric System for Evaluation of the Masticatory Efficiency

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The stomatognathic system is responsible for complex vital functions such as chewing, deglutition, respiration and phonation. Food breakdown is one of the masticatory functions, which enables reducing the attrition against the oral soft tissues and increasing the surface contact of food particles with digestive secretions, thus leading to satisfactory and rapid physiological processes. The methods of evaluation the masticatory efficiency are restricted to electromyography, sieving and clinical observation. However, the validity of these methods has been questioned due to the complexity of the procedures, variances in the material used and inaccuracy of methodologies. This study presents a new method in which a capsule of a synthetic material using fuchsine-containing granules was devised. Such capsules were submitted to several laboratory tests in order to determine their resistance and absorbency. Ten calibrated individuals were instructed to chew the capsules. Masticatory efficiency was determined by analyzing fuchsine concentration in a solution obtained from chewed granules measuring the absorbance at 546 nm. The method was found to be fast, simple, reproducible, inexpensive and efficient and can be used as a complementary evaluation of the masticatory efficiency in different situations.

Key Words: masticatory efficiency, chewing ability, capsule, masticatory function.

INTRODUCTION

Mastication was a subject of great in the beginning of the 20th century. However, this interest has almost completely disappeared and few studies have been conducted in this field. It is one of the most important functions of the stomatognathic system, is the most studied and is particularly relevant. Mastication is defines as a group of stomatognathic phenomena designed for mechanical food processing that includes grinding and breaking down of food into smaller molecules to be swallowed (1). Different terms are used to refer to masticatory function including masticatory efficiency, masticatory ability and masticatory performance (2). This study refers to masticatory efficiency.

Masticatory efficiency is defined as appropriate cycles with compensatory physiological mechanisms resulting from a sensorial mechanism of eruption and attrition developed at different ages, when the temporomandibular junction and muscles are in perfect functional adaptation. Each masticatory cycle consists of several movements of the food within the oral cavity and the mechanical reduction of food by moisture secreted from the salivary glands facilitating volume reduction and deglutition (3).

These movements follow a cycle: the food is trapped, slashed and crushed on one side of the mouth, "shaped" by the tongue, muscles and cheeks and then transported to the other side of the mouth where it finally flows through the inner surface of the anterior upper teeth. The properly masticated and moistened food is ready to be swallowed (4).

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Although there is a range of methods to evaluate the masticatory efficiency, they are not practical in routine clinical practice. The test material is one of the reasons for method inaccuracy. Yurkstas (5) investigated 35 different kinds of food and none of them were found appropriate to test purposes. Food softness or hardness was not considered as a good criterion because, for example, mastication is not needed when eating mashed potatoes. Peanut was characterized as a soft food and raw carrot was considered to be one of the hardest foods. Both are inexpensive, uniform and most people like them as test material. The authors concluded that people with normal dentition could masticate both carrot and peanut with equivalent efficiency. Different natural foods such as peanut (6), nuts (7), almonds (8), carrots (9,10), gelatin (11) and coffee beans (12) have already been used as test materials and some of them are pigmented (10,13). There are no guarantees that the chewed food will have the same physical properties as before. They are dissolved by saliva and water and during deglutition or laboratorial process the material can be lost. The level of pulverization may differ because small particles are sometimes swallowed, jeopardizing the accuracy of the evaluation process. The sieving process is most frequently used. This method involves drying, filtering, weighing and a slow and complicated analysis of the test specimen making it inefficient for clinical analysis. Nakasima et al. (14) developed a test material, a capsule made of synthetic material with stable physical properties, insoluble in saliva. The chewed material can be removed from the mouth and analyzed using a simple laboratory test. Further studies should be done on test accuracy and adapt it to clinical use, widening the scopes for evaluation of the masticatory efficiency in cases of total and removable prostheses, malocclusions, speaking disturbances, missing teeth to improve the life quality of these individuals.

This study presents a new method for evaluation of masticatory efficiency in which capsules of a synthetic material enclosing fuchsine-containing granules were developed.

MATERIAL AND METHODS

Ten individuals, 5 men and 5 women aged 25-30 years were instructed to masticate three capsules during 20 s at three evaluation periods. The volunteers, labeled as A, B, C, D, E, F, G, H, J and I, presented nasal respiration and complete dentition, Class I canine and molar relationship. Three of them wore fixed orthodontic appliances.

A special type of granule was developed as a test material. Its selected pigment, acid fuchsin, was mixed with a small quantity of crystallized cellulose, lactose, corn starch and other components (Table 1). Each granulated pigment was coated with Eudragit E-100 polymeric methacrylate (Rohm Pharma GmbH, Germany). All of these components are listed in the Brazilian pharmacopoeia. The granule was standardized to the size of approximately 1 mm in diameter and crush strength was evaluated by an energy measurement apparatus.

Roughly 245-250 mg of pigmented granules was placed inside 10-mm long rectangular PVC capsules that were welded by radiofrequency. Capsule size, shape and softness were determined to increase comfort during mastication for individuals with different types of dentition. When the capsule was chewed, the granules were broken and fuchsine dye was spread within the capsule according to the chewing strength. Masticatory efficiency was calculated by measuring fuchsine concentration in a solution where water was added to the capsule components.

The amount of fuchsin released upon chewing was measured using a Beckman DU-7 UV-Visible Spectrophotometer (Beckman Inc., Palo Alto, CA, USA). The visible area determined fuchsin absorbance spectrum with 546 nm wavelength as the standard calibration curve (0 - 12.5 μg/mL). After mastication, the capsule contents were dissolved in 5 mL of water under constant stirring for 30 s. The solution was then

Table 1. Granule composition.

Granule components	Amount
Lactose	20.60 g
Crystallized Cellulose	36.85 g
Corn starch	17.10 g
Saccharose	17.10 g
Hydrogenated Oil	8.05 g
Basic fuchsine	0.16 g
Water	60 mL
Coat components	
Eudragit E 100 a 5% acetone	50 mL

filtered to remove the wrapping and non-mashed granules, and the released fuchsine was analyzed based on straight-line equation by calibration curve.

Data were analyzed statically by Kruskal-Wallis non-parametric test using the GMC statistical software package version 2002 (http://www.forp.usp.br/restauradora/gmc/gmc.html).

RESULTS

Individuals A, C, D, E, G and J presented a masticatory cycle of 1 cycle *per* second, whereas individuals B, F, H and I, presented a masticatory cycle of 3 cycles *per* second. Individuals B, F and J were undergoing fixed orthodontic treatment. The values obtained by the volunteers during capsule mastication are shown in the Table 2.

Intra-individual analysis showed that there was no statistically significant differences ($p>0.05$) among the 9 capsules chewed in the three evaluation periods. Inter-individual analysis showed statistically significant difference ($p<0.01$) among the volunteers.

DISCUSSION

The physiology and biophysics of the natural mastication of human beings play an important role to the understanding of the natural development of the stomatognathic system, occlusion, function and action. Therefore, since the beginning of the 20th century, several studies have been conducted to investigate the masticatory function and its importance, focusing on the masticatory efficiency. Evaluation of the masticatory efficiency by sieving process was first seen in the 1920's and has been the most commonly used since then. Several studies on masticatory efficiency have been developed with different test materials using this method (6,8,9,12). However, the sieving process is very complex and it is not possible to completely evaluate its efficiency because some particles are swallowed and some are dissolved by saliva. Pigments have been used in some studies (10,13), but 10% variation has been observed in pigment concentration. In addition, the particles are dissolved jeopardizing the method precision.

Table 2. Values of absorbance of fuchsin release at the 3 evaluation periods.

	Individuals									
	A	B	C	D	E	F	G	H	I	J
	0.0691	0.3270	0.8919	0.5217	0.3474	0.7501	0.4619	0.3270	0.091	0.1204
Time 1	0.2513	0.4610	0.647	0.4980	0.1134	0.7604	0.4134	0.3073	0.0854	0.2066
	0.3070	0.4501	0.5869	0.4034	0.1131	0.7597	0.5203	0.2244	0.1193	0.2574
	0.2515	0.8263	0.3893	0.3681	0.1177	0.7588	0.4969	0.3257	0.1449	0.1311
	0.3726	0.7191	0.7325	0.2149	0.168	0.4403	0.4847	0.3160	0.0956	0.0810
Time 2	0.2837	0.5946	0.6809	0.5324	0.1893	1.0969	0.5124	0.3186	0.0812	0.0795
	0.4067	0.7306	0.3639	0.5344	0.2187	1.0978	0.7011	0.3257	0.1139	0.0884
	0.3484	0.7893	0.3657	0.5800	0.2451	0.6561	0.7164	0.4392	0.1164	0.0769
	0.9143	0.6269	0.7891	0.5393	0.2564	0.4766	0.6349	0.23443	0.1160	0.0891
Time 3	0.7637	0.5270	0.6000	0.3480	0.2560	0.2803	0.6261	0.1997	0.0947	0.0831
	0.3545	0.9429	0.6130	0.8463	0.1579	0.7194	0.4891	0.1654	0.0934	0.2221
	0.2067	0.5647	0.8753	1.1493	0.2324	0.8740	0.4429	0.4521	0.1173	0.0716
Average	0.3744	0.629	0.628	0.544	0.201	0.721	0.546	0.303	0.105	0.125
SD	± 0.2353	± 0.178	± 0.183	± 0.244	± 0.07	± 0.24	± 0.1	± 0.08	± 0.01	± 0.06
Variation (%)	0.05	0.031	0.03	0.05	0.005	0.05	1	0.7	0	0

In the capsule method, the test material is promptly evaluated and has stable physical properties (14). The method was adapted to the conditions of this study and the physical properties were preserved. The advantage of the capsule is that its material is fully obtained from the mouth, with no danger of being swallowed nor dissolved by saliva. Laboratory processing is fast and effective and allows determining exactly the patient's masticatory efficiency. The capsules are not torn nor ripped during mastication, and thus the granules are kept inside the capsule. All granule components are listed in the Brazilian pharmacopoeia and can be reproduced.

Statistical analysis showed that this method is 99% reliable, sensitive and reproducible. No significant intra-individual variation was observed, which means that chewing of an individual is the same at any moment as far as the same functions and biological conditions are present. Inter-individual analysis showed statistically significant variation, i.e., variation in masticatory efficiency among the volunteers, which proved that the test is sensitive.

Mastication is influenced by several factors including mandibular and tongue movements, perioral muscle activities, bite tensions and hard oral surfaces. However, it has not yet been defined which one is the most important (15).

Phillips (16) observed that real bite tensions during chewing are normally greater in men than in women because of male muscular constitution . In this study, the masticatory efficiency of women was greater than that of male volunteers. It may indicate that masticatory efficiency is not totally related to muscular force. As the major goal of this study was to develop and evaluate a method to assess masticatory efficiency, the sample size was not enough to set forth any conclusions regarding differences between genders. Further studies are necessary to investigate this possibility.

Ahlgren (17) calculated that the duration of the masticatory cycle is variable, according to food consistency or resistance. Masticatory frequency and masticatory strikes *per* second vary depending on food hardness. In this study, mastication time was 20 s. Masticatory frequency varied among individuals into two groups: 1 cycle *per* second (individuals A, C, D, E, G and J) and 3 cycles *per* second (individuals B, F, H and I). In view of these results, it may be inferred that cycle frequency does not interfere with total food degradation or with a greater masticatory efficiency. Individuals with 1 cycle/s masticatory cycle showed respectively the greatest and the least masticatory efficiency.

Having normally occluded and correctly aligned mandibular teeth is considered very important. Teeth must be disposed within the dental arch in such a way that the masticatory force can be uniformly distributed; otherwise parts of the stomatognatic system will be affected leading to an inadequate masticatory performance. This situation can be observed in the individuals under orthodontic treatment. Even presenting Class I canine and molar relationship, they presented some misaligned or displaced teeth and masticatory efficiency was lessened.

The findings of this study showed that the tested method is fast and effective to evaluate masticatory efficiency and can be easily reproduced. However, further research is required. This new research line allows evaluating and comparing the masticatory efficiency in adults and children, dentate or edentulous, with any type of dentition. This will allow the performance of studies that will contribute to improve the diagnosis in preventive and rehabilitation treatments.

RESUMO

O sistema estomatognático é responsável por funções complexas vitais para o organismo como a mastigação, deglutição, respiração e fonação. A função mastigatória destina-se a dividir os alimentos, diminuindo o atrito contra os tecidos moles da boca e aumentando a superfície de contato entre os alimentos e as secreções digestivas, possibilitando um processo fisiológico adequado e rápido. As possibilidades de avaliação desta função está restrita ao uso das eletromiografias, das tamises e da observação clínica. No entanto, há divergências quanto à validade destes métodos devido à complexidade dos procedimentos, variações dos materiais-teste utilizados e à imprecisão das metodologias empregadas. Este trabalho apresenta uma cápsula de material sintético dentro da qual estão contidos grânulos que apresentam fucsina básica em sua composição. Essas cápsulas passaram por vários testes laboratoriais para determinação de sua resistência e de sua absorbância. Dez indivíduos foram instruídos a mastigar estas cápsulas. A eficiência mastigatória foi determinada através da concentração da pigmentação de fucsina numa solução obtida dos grânulos mastigados por meio da medida da absorbância em 546 nm. Foi demonstrado que o método é rápido, simples, reprodutível, de baixo custo e eficaz e pode ser usado como método complementar para a avaliação da eficiência mastigatória em diferentes situações.

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