Influence of Mastication on Gastric Emptying

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INTRODUCTION

The role of mastication in the digestive process, although recognized since the Roman age (prima digestio fit in ore—that is, early digestion is in the mouth), has received little interest in both dental and medical literature. Most published papers deal with the relationship between chewing efficiency and dentition (Helkimo et al., 1978; Gunne and Wall, 1985; Slagter et al., 1993; Boretti et al., 1995; Pera et al., 1998), and the few that examine the influence of mastication on the digestive process give contrasting results. An epidemiological study (Mercier and Poitr et al., 1992) on 142 subjects with inadequate chewing observed a 60% prevalence of current digestive complaints, such as burning sensation, bloating, cramps, constipation, or diarrhea; the disorders improved in 83% of the patients after correction of the masticatory dysfunction. By contrast, a study on edentulous subjects wearing dentures (Poitr et al., 1995) found that gastric trituration and the emptying of solid foods are not facilitated by prior mastication.

The aim of the present study was to evaluate whether, in subjects with normal healthy dentition, the gastric emptying rate of solid food changes in relation to the number of masticatory cycles and is related to the degree of food trituration.

MATERIALS & METHODS

Study Subjects

The study was performed on 12 healthy non-smoking dental students, nine men and three women, with ages ranging from 18 to 35 yrs, and a body weight within 10% of their ideal value. All the subjects had a complete natural healthy dentition with no subjective or clinical disorders in the masticatory or digestive system. The protocol of the study was approved by a local ethics committee, and informed consent was obtained by each study subject.

Study Protocol

The subjects were examined on two separate occasions, one week apart, in the morning after overnight fasting, when they consumed the same test meal, divided into five equal portions. The meal had a total caloric value of 250 kcal and consisted of one egg cooked with butter (10 g), whose yolk was dosed with 100 mg 13C-octanoic acid (Cortesitalia, Corsico, Milan, Italy), ham (21 g) cut into 5-mm cubes, crackers (25 g), and 500 mL of water. The subjects consumed the test meal in the sitting position over a period of no more than 10 min, with their usual chewing pattern, but on one session they chewed all the foods with 50 masticatory cycles, while on the other session they chewed only the egg and crackers for 25 cycles, and swallowed ham cubes whole. The order of the tests was randomized.

Measurement of Gastric Emptying Rate

Gastric emptying was measured by means of the 13C-octanoic acid breath test (Ghoos et al., 1993; Choi et al., 1997; Cheng and Lee, 1999). Octanoic acid is a
medium-chain fatty acid, rapidly absorbed in the duodenum, whose oxidation in the liver results in excretion of labeled carbon dioxide (\(^{13}\)CO\(_2\)) into breath. \(^{13}\)CO\(_2\) can easily be measured in expired air, by means of isotope ratio mass spectrometry. Breath samples were collected at baseline before subjects ate the test meal (2 samples) and, after meal ingestion, every 15 min for the first hour (4 samples) and every 30 min for the following 3 hrs (6 samples). Breath samples were collected from subjects blowing directly into special pipettes impermeable to CO\(_2\) (Vacutainer System, Franklin Lakes, NJ, USA), using a straw to blow into the bottom of the tube. \(^{13}\)CO\(_2\) was measured by means of a mass spectrometer (Breathmat, Finnmann Mat, Brema, Germany) operated by a technician who was blinded to the experimental conditions. The \(^{13}\)CO\(_2\) recovered in breath was expressed as percentage per hr of the administered amount.

From the \(^{13}\)CO\(_2\) excretion curve, the following parameters of gastric-emptying rate were calculated, according to the formulae suggested by Ghoos et al. (1993): (1) the lag phase (T\(_{lag}\)), that is, the initial delay of the \(^{13}\)CO\(_2\) excretion curve, representing the time needed for antechannel contractions to grind solid particles to a diameter small enough to pass through the pylorus (equal or lower than 1 mm); and (2) the half-emptying time (T\(_{1/2}\)), that is, the time required for half of the gastric contents to transit through the pylorus.

**Measurement of Trituration Performance**

The degree of trituration was estimated with the use of sieves (Othoff et al., 1984). For this test, only ham could be used, since both egg and crackers may stuff the sieve holes, thus blocking the passage of other food particles. Each subject was invited to chew 21 g of 5-mm ham cubes for 50 cycles and then to spit the masticated ham into three sieves stacked on top of each other, with holes progressively decreasing in size from top to bottom (2 mm, 1 mm, and 0.6 mm), under a water stream flowing at constant pressure of 1 atmosphere for 30 sec.

The material held by each sieve was collected, dried, and weighted. The quantity filtered by each sieve was expressed as the percentage of the total filtered test food. Trituration performance was expressed as the percentage of particles equal to or below 1 mm recovered after subjects chewed. Actually, 1 mm is the maximum diameter for solid particles to pass through the pylorus.

**Statistical Analysis**

The Student’s t test for paired data was used to compare the gastric emptying rates obtained with 50 and 25 chewing cycles. Pearson’s linear correlation test was used to evaluate the relationship between trituration performance (percentage of ham particles ≤ 1 mm) and both T\(_{lag}\) and T\(_{1/2}\) obtained with 50 chewing cycles. For each test, a P level below 0.05 was considered statistically significant.

**RESULTS**

All the subjects had values of gastric emptying rates within the range found in normal subjects (Ghoos et al., 1993), that is, 32 ± 20 min for T\(_{lag}\) and 72 ± 22 min for T\(_{1/2}\). The comparison between the two mastication patterns showed that both T\(_{lag}\) and T\(_{1/2}\) were significantly shorter when the meal was chewed for 50 cycles than when it was chewed for 25 cycles and ham cubes were swallowed whole: The T\(_{lag}\) decreased from 36.4 ± 4.1 min to 25.9 ± 3.8 min, p = 0.017; the T\(_{1/2}\) decreased from 62.5 ± 6 min to 49.1 ± 5.7 min, p = 0.009 (Table). The results of the sieve test showed that trituration performance (percentage of ham particles ≤ 1 mm after 50 chewing cycles) was inversely related to both T\(_{lag}\) (r = 0.621, p = 0.031) and T\(_{1/2}\) (r = 0.699, p = 0.012) (Fig.).

**DISCUSSION**

The results of this study indicate that gastric emptying rate is significantly influenced by masticatory efficiency. In fact, both T\(_{lag}\) and T\(_{1/2}\) were significantly shorter when the test meal was chewed for 50 cycles than when egg and crackers were chewed for 25 cycles only and ham cubes were swallowed whole. This means that adequate mastication shortened the time needed by the stomach to comminate food particles to a diameter small enough to pass through the pylorus. The shortening of gastric emptying produced by adequate chewing was consistent, about 10 min for T\(_{lag}\) and 13 min for T\(_{1/2}\). This difference is relevant, considering that the test meal was composed of a small quantity of soft and easily masticable ingredients. It is presumed that
with an abundant meal containing hard foods, the influence of mastication on gastric emptying would have been much greater. The results of the sieve test further support the hypothesis that adequate food trituration shortens gastric emptying. In fact, the percentage of ham particles ≥ 1 mm observed after 50 chewing cycles was closely inversely related with both T_{lag} and T_{1/2}.

In contrast to our findings, in Poitras et al.'s study (1995), gastric emptying was not influenced by mastication. This might depend on the fact that subjects wore complete dentures for edentulism, and dentures cannot provide a masticatory function as efficient as that of natural dentition (Kapur et al., 1964; Helkimo et al., 1978; Jenet, 1981). In this study, gastric emptying was measured by traditional scintigraphy. The present study used 13C-octanoic acid breath test as a measure of gastric emptying rate. This method of breath microanalysis has given results similar to those obtained by scintigraphy (Choi et al., 1997; Galmiche et al., 1998), with the advantage of the use of a stable isotope (13C) and the need for only inexpensive equipment (Cheng and Lee, 1999). Unfortunately, the 13C-octanoic acid breath test is influenced by interindividual differences in intestinal absorption, liver oxidation, and breath excretion (Maes et al., 1995; Choi et al., 1997). However, these factors might not be relevant in our study, since each subject was his/her own control. Also, food composition should not influence gastric emptying (Weiner et al., 1982) in the present study, since the meal was identical for the two sessions, the only substantial difference being ham mastication.

In conclusion, the results of this study demonstrate that mastication has a significant influence on the digestive process. Mal digestion might be the consequence of inadequate mastication, and the assessment of chewing efficiency should be included in the diagnostic work-up of digestive disorders.

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REFERENCES