Odontology (2023) 111:728–733
https://doi.org/10.1007/s10266-022-00777-7

ORIGINAL ARTICLE

Masticatory path pattern and masticatory performance while chewing gummy jelly

Hiroshi Shiga[1] · Kunihisa Nakajima[1] · Masaoki Yokoyama[1] · Marie Komino[1] · Hanako Uesugi[1] · Mako Sano[1] · Ichiro Arakawa[1] · Takashi Oh[1]

Received: 23 September 2022 / Accepted: 4 December 2022 / Published online: 23 December 2022

Abstract

The purpose of this study was to clarify masticatory path pattern and masticatory performance during gummy jelly chewing. A total of 235 healthy adults were asked to chew gummy jelly for 20 s on each side, and the masticatory movement was recorded using a Motion Visi-Trainer (MVT V1). Next, the amount of glucose extraction was measured as a parameter of masticatory performance. The masticatory path was classified into one of five patterns newly devised: normal pattern (N, opening: straight or concave, closing: convex) and abnormal patterns (A1–A4). The number of occurrences of each pattern was investigated and compared by sex and path pattern. Next, masticatory performance was compared between the normal pattern and the abnormal patterns by sex. Pattern N was the most frequently expressed in 346 cases out of 470 cases (73.6%), followed by patterns A1, A4, A2, and A3 in that order. Regarding the number of patterns observed, pattern N was the most common in both sexes, followed by pattern A1, with no significant difference between sexes. The amount of glucose extraction in each pattern was the highest in pattern N for both sexes, followed by A2 and others in that order, and a significant difference was observed between the normal pattern and the abnormal patterns. From these results, the existence of sex difference in masticatory path patterns during gummy jelly chewing was not proven, and that masticatory performance was higher with normal patterns than with abnormal patterns.

Keywords Masticatory function · Masticatory movement · Masticatory performance · Gummy jelly · Path pattern

Introduction

To objectively evaluate masticatory function, attempts have been made to investigate masticatory performance, occlusal force, muscular activity, and masticatory movement [1–8]. Various methods have been reported for masticatory performance, but a method that measures the amount of glucose extraction during gummy jelly chewing has been reported, and a significant positive correlation has been observed between it and the sieving method, which is the gold standard [9]. In addition, it has been shown that it can be improved by dental treatment [10–12], and that there is a reference value, [13] etc. For these reasons, it has become widely used.

Attempts have been made to investigate the amount of movement, the movement rhythm, and the pattern of the path during chewing. Of these, the movement path seen on the frontal plane is classified into several patterns [14–18]. The authors could classify masticatory movement paths into six types of patterns, using three types of opening path and two types of closing path, and seven types of patterns (I–VII) including pattern in which the opening and closing paths crossed. It has also been shown that there are two types of representative patterns (I and III) [18]. According to studies that investigated the patterns of movement path before and after dental treatment using the authors' classification method [2, 4], patterns I and III increased after dental treatment. There has also been a study analyzing the pattern of the movement path by treating patterns I and III as normal patterns and other patterns as abnormal patterns [19]. However, functional differences between normal and abnormal patterns have not been demonstrated.

On the other hand, pattern I and pattern III, which are regarded as normal patterns, have the same closing path

✉ Hiroshi Shiga
h-shiga@tky.ndu.ac.jp

[1] Department of Partial and Complete Denture, School of Life Dentistry at Tokyo, The Nippon Dental University, 1-9-20 Fujimi, Chiyoda-Ku, Tokyo 102-0071, Japan

(straight or convex) and different opening paths (I: straight or concave path, III: path toward the working side after toward the non-working side). However, since pattern III is concave toward the working side after opening to the non-working side, it is considered possible to make one pattern by setting the opening paths of both patterns as "straight or concave". In addition, four types of patterns can be derived from two types of opening path and two types of closing path, and five types of patterns can be derived when a pattern in which opening and closing cross is included. They can be classified as one type being a normal pattern and four types being abnormal patterns. In the present study, based on these ideas, we decided to define five new masticatory path pattern classifications, consisting of one normal pattern and four abnormal patterns.

Therefore, in this study, to clarify the presence or absence of functional differences between the normal and abnormal patterns of masticatory movement paths, the movement of the mandibular incisal point and the amount of glucose extraction when healthy subjects chewed gummy jelly were recorded. After classifying the masticatory path patterns into five types using a newly devised classification method, the amounts of glucose extraction in normal and abnormal patterns were analyzed.

Materials and methods

Ethics statement

This study was approved by the ethics committee of The Nippon Dental University School of Life Dentistry (NDU-T2012-29). Informed consent was obtained from all subjects prior to their participation in the study after an explanation of the purpose of the study.

Subjects

A total of 235 healthy adults with natural dentition (132 males, 103 females; age 20–46 years, mean age 34.3 years) participated in this study. The sample size was calculated using a software program (G*Power 3.1.9.3), with α of 0.05, power of 0.8, and effect size (w) of 0.3, requiring 170 cases.

The subjects consisted of staff and students of Nippon Dental University. The inclusion criteria were: (1) no clinical abnormalities in the masticatory system; (2) natural dentition, excluding third molars; and (3) no occlusal complaints. The exclusion criteria were: (1) previous orthodontic treatment; and (2) signs and symptoms of temporomandibular disorders and maxillofacial pain.

Test food

The test food used was a cylindrical gummy jelly with a diameter of 14 mm, height of 8 mm, and weight of about 2 g. Gummy jelly comprised 41% of reduced sugar syrup, 22% maltitol, 20% sorbitol, 5% glucose, and 8% gelatin.

Recording method

Before the experiment, the subjects were asked to freely chew one gummy jelly to get used to chewing gummy jelly.

The movement of the incisal point was recorded with a Motion Visi-Trainer (MVT V1, GC, Tokyo, Japan) when the subjects chewed gummy jelly for 20 s on each side. Next, the amount of glucose extraction was measured as a parameter of masticatory performance when subjects chewed gummy jelly for 20 s on each side (Fig. 1).

Classification of movement path patterns

For ten cycles from the 5th to the 14th after the start of mastication, the movement path was superimposed, and the

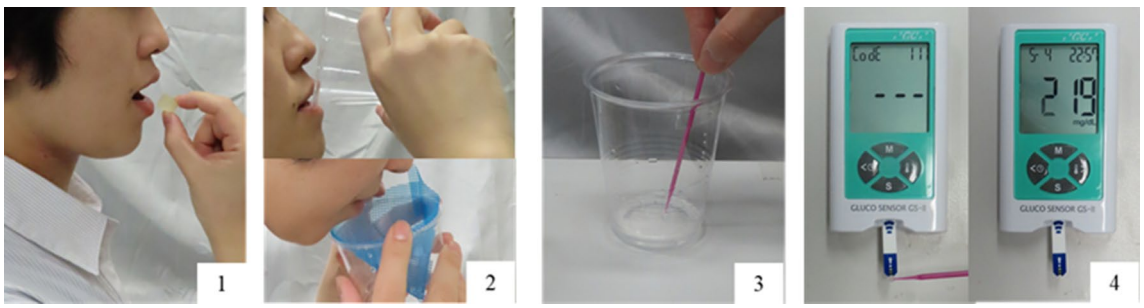

Fig. 1 Procedures for measuring masticatory performance. (1) Have the subject chew the gummy jelly on the unilateral side for 20 s. (2) After chewing, have the subjects hold 10 ml of water in the mouth and then spit it out along with the gummy jelly. (3, 4) Lightly stir the cup, collect the filtrate with a brush, and place it on the sensor tip. The glucose concentration will be displayed a few seconds later. This measurement is the amount of glucose extraction

average path was displayed. The masticatory movement path patterns were classified into one of five types, N and A1 to A4, including four patterns consisting of a combination of two types for the opening path (o1: straight or concave, o2: convex) and two types for the closing path (c1: straight or convex, c2: concave) (N: o1–c1, A1: o1–c2, A2: o2–c1, A3: o2–c2), and a pattern (A4) in which the opening and closing crossed (Fig. 2).

Statistical analysis

All data were analyzed using statistical software (SPSS for Windows 27.0, IBM Corp., Armonk, NY, USA). After classifying the left and right (470 sides) movement path patterns of all subjects into five types, the number of occurrences of each pattern was investigated and compared by sex and movement path pattern. Next, masticatory performance was compared between the normal pattern (N) and the abnormal patterns (A1-A4) by sex. The relationship between sex and pattern of movement paths was assessed by chi-squared test. Normal and abnormal patterns were compared by the independent *t* test after confirming data normality by the Shapiro–Wilk test. All statistical analyzes were performed with the level of significance set at a *P* value of 0.05.

Results

Pattern N was the most frequent, seen in 346 (73.6%) of 470 cases, followed by pattern A1 in 61 (13.0%), A4 in 31 (6.6%), A2 in 17 (3.6%), and A3 in 15 cases (3.2%). The majority of subjects (74.5%) showed pattern N. Regarding the patterns in males and females, pattern N was the most common in both males and females, followed by pattern A1 (Table 1), and no significant difference was observed between the sexes ($\chi^2 = 1.587$, $P = 0.818$).

The amount of glucose extraction in each pattern was the highest in pattern N for both sexes, followed by A2 and the others in that order (Table 2). A significant difference in the amount of glucose extraction was observed between the normal pattern (N) and the abnormal patterns (A1-A4) ($P < 0.001$).

Discussion

Chewing gum [1, 2, 4, 7, 14, 16, 18, 20–24], bread [15], gummy jelly [4, 19], carrots [14], peanuts [14], wine gum [15, 22], etc. are used as test foods for research on the

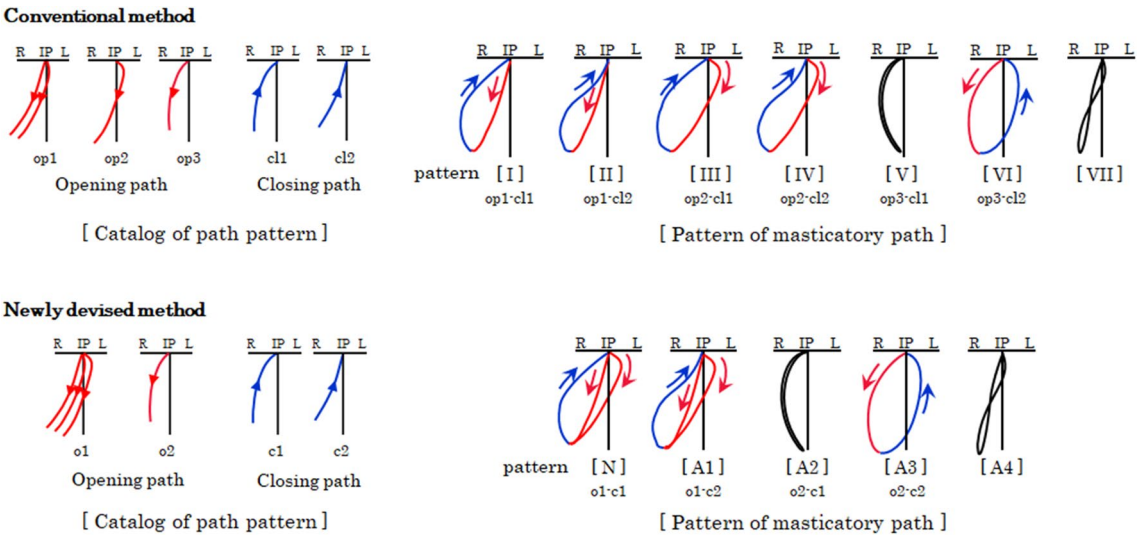

Fig. 2 Catalog of path pattern and pattern of masticatory path. *IP* intercuspal position, *R* right side, *L* left side, *N* normal pattern, *A1–A4* abnormal pattern

Table 1 Frequency of each pattern in males and females

	N	A1–A4	All	A1	A2	A3	A4
Male	189	75	264	36	10	10	19
Female	157	49	206	25	7	5	12
Male and female	346	124	470	61	17	15	31

N normal pattern, *A1–A4* abnormal pattern

Table 2 Amount of glucose extraction of each pattern in males and females

	N	A1–A4	A1	A2	A3	A4
Male						
Mean	214.5	178.1	178.6	183.5	177.1	174.4
SD	28.4	25.1	28.3	17.7	25.2	22.1
Female						
Mean	204.0	175.6	176.9	186.3	178.6	175.6
SD	28.0	33.7	33.5	38.7	28.4	33.6

N normal pattern, *A1–A4* abnormal pattern, *SD* standard deviation

patterns of the masticatory movement path. Of these, studies using softened chewing gum [2, 4, 16, 18, 21] are the most common, but chewing gum is not recommended for denture wearers because of its stickiness. Gummy jelly is non-adhesive and is considered to be equivalent to chewing gum [25]. Glucose-containing gummy jelly can also be used to assess masticatory performance. For these reasons, gummy jelly was used as the test food in the present study.

It has been reported that there is a difference between males and females in the amount of movement and the movement rhythm, but no difference between sexes in the stability of movement and the pattern of the movement path [26]. However, since there was a difference between sexes in masticatory performance, it is suggested that attention should be paid to sex differences in the analysis [27]. Therefore, the purpose of the present study was to clarify the presence or absence of differences between the normal and abnormal patterns of the masticatory path in terms of masticatory performance.

The movement path during mastication can be classified into several patterns, and it has been shown that those with normal occlusion have a regular pattern, and those with malocclusion have an irregular pattern [2, 14–17, 28]. It was reported by Kobayashi et al. [18], who investigated the patterns of movement paths during mastication of softened chewing gum, that pattern N in the present study accounted for 74.5% of the total. In the present study, which examined the patterns of movement paths during chewing of gummy jelly, pattern N accounted for 73.6% of the total, consistent with the report by Kobayashi et al. [18].

This is probably because the gummy jelly used in the present study is a soft food like softened chewing gum, and, therefore, the results were almost the same. According to a study that investigated the patterns of movement paths before and after dental treatment, it was reported that patterns other than pattern N in the present study were observed before treatment, but pattern N increased after treatment [2, 4].

In the present study, there were two types of opening and closing paths (normal and abnormal), and four patterns were created by combining them. A normal pattern (N) was defined when both the opening and closing paths were normal, and the rest were abnormal patterns (A1–A3). In addition to these patterns, a pattern in which the opening and closing crossed was added as an abnormal pattern (A4), resulting in five types of patterns. Thus, the two conventional types of normal patterns were considered one type, and the other patterns were treated as abnormal patterns, making it possible to clearly distinguish between normal and abnormal patterns, with classification easier than ever before. There is no demerit that arises from combining these two types of patterns into one type of pattern.

In a study that analyzed movement path patterns by classifying them into three types (normal and abnormal (reverse and crossover)), it was reported that patients with cleft lip and palate had more abnormal patterns than those with normal occlusion [24], and that abnormal patterns decreased and normal patterns increased after orthodontic treatment [7, 23]. Comparing the normal patterns in their study and the present study, both were "concave or straight" in the opening path, but in the closing path, in the present study it was "convex"', but in their study they included "concave" in addition to "convex" as a normal pattern. However, there is other study that classified a concave closing path as abnormal, as in the present study [1]. In this regard, a study that investigated the masticatory function of two patterns (convex and concave) with different closing paths showed that the integral value of masseter muscular activity and the amount of glucose extraction were larger and the mastication movement was more stable in the pattern with a convex closing path than in the pattern with a concave closing path. They reported that there was a functional difference between the two types of patterns, and that the pattern with a convex closing path had superior masticatory function [29]. It has also been reported that, when experimental occlusal interference was induced in a healthy subject, the concave closing pattern, which was hardly seen before interference, remarkably increased, and the movement became unstable [30]. In addition, many of the previous studies distinguished between these two kinds of patterns. Furthermore, in the present study, the mean values of glucose extraction in the abnormal pattern and in the pattern (A1) in which the closing path was concave were close to each other. In the present study, because the sample size of each abnormal pattern was small,

the difference in the mean value between the normal pattern and each abnormal pattern was not examined. However, it can be easily presumed that the amount of glucose extraction in pattern A1 is significantly smaller than that in pattern N. From these facts, it seems that there is no problem in treating concave closing paths as abnormal patterns [14–18].

Conclusion

To clarify the presence or absence of functional differences between normal and abnormal paths, the movement of the incisal point and the amount of glucose extraction when healthy subjects chewed gummy jelly were recorded. After classifying the patterns of the masticatory path using the classification method devised, the amount of glucose extraction in the normal and abnormal patterns was analyzed. The results suggested that the existence of sex difference in masticatory path patterns during gummy jelly chewing was not proven, and that masticatory performance was higher in the normal pattern than in the abnormal patterns.

Funding The authors received no support from any grant.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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