Objective and subjective hardness of a test item used for evaluating food mixing ability

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SUMMARY The aim of this study was to compare objective and subjective hardness of selected common foods with a wax cube used as a test item in a mixing ability test. Objective hardness was determined for 11 foods (cream cheese, boiled fish paste, boiled beef, apple, raw carrot, peanut, soft/hard rice cracker, jelly, plain chocolate and chewing gum) and the wax cube. Peak force \( N \) to compress each item was obtained from force–time curves generated with the Tensipresser. Perceived hardness ratings of each item were made by 30 dentate subjects (mean age 26.9 years) using a visual analogue scale (100 mm). These subjective assessments were given twice with a 1 week interval. High intraclass correlation coefficients (ICCs) for test–retest reliability were seen for all foods (ICC > 0.68; \( P < 0.001 \)). One-way ANOVA found a significant effect of food type on both the objective hardness score and the subjective hardness rating \( (P < 0.001) \). The wax cube showed significant lower objective hardness score (32.6 N) and subjective hardness rating (47.7) than peanut (45.3 N, 63.5) and raw carrot (82.5 N, 78.4) \( [P < 0.05; \text{Ryan–Einot–Gabriel–Welsch (REGW)}-F] \). A significant semilogarithmic relationship was found between the logarithm of objective hardness scores and subjective hardness ratings across twelve test items \( (r = 0.90; P < 0.001) \). These results suggest the wax cube has a softer texture compared with test foods traditionally used for masticatory performance test, such as peanut and raw carrot. The hardness of the wax cube could be modified to simulate a range of test foods by changing mixture ratio of soft and hard paraffin wax.

KEYWORDS: food texture, hardness, food mixing ability, masticatory function

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Introduction

In trying to evaluate the effects of tooth loss and prosthetic rehabilitation on masticatory function, a variety of physical changes [oral sensation (1, 2), muscle effort (3–7), mandibular movements (5, 8)] have been evaluated. In addition, effects of aging or hardness of gelatin-based model food able to swallow have been evaluated. However, the most common index of mastication has been the degree of bolus comminution. Hard and brittle natural foods such as peanuts and raw carrots (9–13), food substitutes not designed for swallowing (silicone rubber) (4, 13–16), have been predominantly employed as test items to evaluate masticatory performance (ability to comminute food). A gelatin-based model food designed to be swallowed has been utilized to test effect of aging or hardness of the model food on muscle effort and mandibular movement (17, 18). A number of studies have shown that food type effects the particle size distributions of the masticated bolus (4, 11–13, 19, 20). Clearly, the masticatory performance score is dependent on the characteristics of the test item. Since common diets include foods with a variety of textures,
utilizing hard and brittle test foods for evaluation of masticatory function may limit the generalization of effects of prosthodontic rehabilitation. Masticatory tests using items having mechanical properties which contrast to those of traditional items may provide additional insight into prosthodontic treatment effects on masticatory ability for the range of food items in the varied diet common to the majority of adults.

New methods have been developed for assessing mastication of foods less difficult to chew than peanuts, carrot, or beef, using test items that are relatively soft and cohesive, such as chewing gum (21–23) or paraffin wax (24). A two-coloured paraffin wax cube (12 × 12 × 12 mm) has been developed (24) to estimate food kneading and mixing ability (Mixing Ability Test) with softer, non-brittle foods (Fig. 1). The Mixing Ability Test utilizes a temperature controlled wax cube as a bolus that the subject chews for 10 strokes on the directed side of the mouth. An Mixing Ability Index is derived from digital image analysis of the colour mixture and shape of the chewed cube. The reliability, validity and responsiveness of the Mixing Ability Test have been investigated in previous studies (25, 26). However, the physical properties of the wax cube have not been evaluated, and it is not clear how the physical characteristics of the wax cube relate to test items more commonly used in evaluation of masticatory ability. The wax cube used in previous studies (24–26) was made of equal weight mixture of hard paraffin wax (PW-140*) and soft paraffin wax (Hi-Mic-1045*) (Table 1). The mixture ratio of the two paraffin waxes can be changed. However, effect of the mixture ratio on the physical characteristics of the wax cube has not been evaluated.

Food texture has been defined as being a product of the multiple physical and sensory properties of a food, such as hardness, cohesiveness, springiness, adhesive-

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objective and subjective hardness (study-1); and 2) the mixture ratio of the two paraffin waxes (PW-140 and Hi-Mic-1045) does not affect the objective and subjective hardness of wax cube (study-2).

Materials and methods

Study-1: Comparisons wax cube to natural foods

Subjects. The 30 participants in the study were completely dentate and balanced for gender (15 males and 15 females, mean age 26.9 ± 2.2 years). Subjects were recruited from the students and staff of Tokyo Medical and Dental University. Applicants with severe periodontal disease and clinical signs or symptoms of temporomandibular disorder, psychological disease, neurological disorders and salivary dysfunction were excluded. In this study, none of subjects had previous experience with subjective assessment of food texture. All study related procedures and tests were approved by the Ethical Committee at Tokyo Medical and Dental University. Each subject received a written and oral description of the study and informed consent was obtained before enrolment into the study.

Test items. Objective and subjective methods were used to evaluate the wax cube used in the Mixing Ability Test (24) and 11 foods ranging in texture. Cream cheese, boiled fish paste (kamaboko), jelly, chewing gum (4.2 g), raw carrot, pared raw apple, boiled beef (loin, 30 min, 80 °C), plain chocolate, soft rice cracker, hard rice cracker and peanut were selected from foods used in previous studies on objective masticatory function (3, 5–13) or chewing ability (33, 39, 40). Most of the test foods would be present in the diets of many people with a variety of dentition categories. The foods used were purchased in a local Japanese supermarket.

Test pieces of cream cheese, boiled fish paste, jelly, carrot, apple, beef and chocolate were sliced to 12 × 12 × 12 mm size equal to the wax cube. For both the soft and hard rice cracker, the original thickness was preserved (12 mm long × 12 mm wide × 7 mm thick). For peanuts, a half peanut with an original ellipsoid form (approximately 16 mm long × 7 mm wide × 5 mm thick) was employed in this study.

Hardness evaluations. Objective physical assessments of the twelve test items were made with the Tensipresser (TTP-50BXII). The principle for measurement of hardness with this instrument was based on Texture Profile Analysis (29). Figure 2 shows the schematic presentation of measurement with this instrument, and Fig. 3 shows the pyramid-shape plunger (90–120°) used in this study to simulate the form of a maxillary lingual cusp (30, 32). The base plate moved upward at constant speed (cross-head speed: 10 mm s⁻¹) to a position where distance between a tip of the plunger and surface of the base plate was 60% of the thickness of an original test piece (compression rate: 40%). For example, when a test piece of 12 mm thick was measured, the base plate moved upward to a distance 7.2 mm from the tip of the plunger. Then, the base plate returned to original position (Fig. 2). The load cell connected to the plunger sensed the force applied during this movement. The resulting force-time curve was evaluated to determine the highest peak force (objective hardness; N) achieved for each test item (Fig. 4). The compression rate of 40% was chosen for all pieces in accordance with a testing condition of a previous study (30). A preliminary experiment found that maximum velocity of mandibular first molar measured with an optoelectronic device ( Gnathohexagraph system) on the chewing side during closing phase of a single bite ranged from 81 to 119 mm s⁻¹ for the 12 test items (n = 4). However, a cross-head speed of 10 mm s⁻¹ was the maximum for the Tensipresser. The detail techniques of measurement and analysis of mandibular movements using this device have been described in a previous study (41).

Objective force evaluation was made for 10 samples of each test item. Mean maximal peak forces from the 10 pieces for each test item were used for statistical analyses of hardness. Before assessment of temperature

Table 1. Physical property of paraffin wax used in wax cube

<table>
<thead>
<tr>
<th></th>
<th>PW-140</th>
<th>Hi-Mic-1045</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point (°C)</td>
<td>60-8</td>
<td>70-1</td>
</tr>
<tr>
<td>Penetration (25 °C)</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td>Penetration (35 °C)</td>
<td>16</td>
<td>103</td>
</tr>
<tr>
<td>Viscosity (mm² s⁻¹; 210 °F)</td>
<td>4-192</td>
<td>–</td>
</tr>
<tr>
<td>Viscosity (mm² s⁻¹; 100 °C)</td>
<td>–</td>
<td>14-81</td>
</tr>
<tr>
<td>Density (g cm⁻³; 25 °C)</td>
<td>0.913</td>
<td>0.915</td>
</tr>
</tbody>
</table>

N. M. SALLEH et al.

sensitive items (chewing gum, chocolate and wax cube), the plunger was placed in a warm water chamber (37 °C) for 5 min. The wax cube was maintained at 37 °C until measurement. Chewing gum was formed into an approximately 12 x 12 x 12 mm cube by hand by one operator (NS) after chewing for 2 min. The chewing gum was assessed at body temperature. The rest of the test pieces were assessed at room temperature (23–24 °C).

Subjective assessment was made on the basis of prior methods for evaluating food texture (27, 28). In this study, subjects were asked to bite down on a test piece once, between the molar teeth on their preferred chewing side, evaluating how hard the food was to bite on. They were not told how hard to bite the test piece. Chewing gum was formed into a bolus by each subject intraorally with cheek and tongue after chewing for 2 min. Preparation and condition of the rest of test pieces was the same as for the objective assessments.

A VAS with anchors at the ends of the 100-mm line was used to measure subjective hardness (6, 17, 35, 42–44). The anchor on the left end of the VAS was defined as ‘very soft’, and the anchor on the right end of the VAS was ‘very hard’. Subjects were instructed to mark a vertical line at a point on the VAS indicating the appropriate hardness for each test piece. The method for assessing hardness was explained to each subject before assessments.

Twelve assessments were made during a trial for each subject. In each trial, one piece of each of the 12 items was given to the subject, in a random order. The order differed among subjects. Three trials were given at one session (first, second and third trials). In addition, to evaluate test–retest reliability, subjects participated in a second session (fourth, fifth and sixth trials) 1 week later. The mean distance from the left anchor to the vertical mark on the VAS was defined as the subjective hardness rating for each item. Subjects did not have any
prior experience with subjective assessment of foods and they were not calibrated against each other for standardization of assessments. Additionally, they did not receive a scale of standard foods for reference. Therefore, measures from the first trial for each session (first and fourth trials) were treated as learning trials and excluded from all analyses. Only the measures from the second and third trials of each session (trials 2, 3, 5 and 6) were used for statistical analysis.

Study-2: Effect of the mixture ratio on hardness of wax cube

Two new formulations of wax cube, a softer wax cube (SWC, 80 weight % of Hi-Mic-1045) and a harder wax cube (HWC, 40 weight % of Hi-Mic-1045) were developed. SWC and HWC have different mixture ratios compared with original wax cube (OWC, 50 weight % of Hi-Mic-1045) used in study-1 and previous studies (24–26). Objective assessments of 10 test pieces for SWC and HWC were made using the same methods in study-1 and previous studies. Objective hardness scores for OWC obtained in study-1 were used for statistical comparisons with SWC and HWC. Ten subjects (six male and four female) selected randomly from participants in study-1 participated in subjective assessments of SWC, HMC and OWC in study-2. Subjective assessments were made using the same methods in study-1 at one session (first, second and third trials), and only the measures from the second and third trials (trials 2 and 3) were used for statistical analysis.

Statistical analysis

Study-1: Comparisons wax cube to natural foods

Objective hardness. A one-way analysis of variance (ANOVA) was used to test the effect of food type on objective hardness score. For post-hoc comparisons, the Ryan–Einot–Gabriel–Welsch (REGW) F multiple range test (45) was used due to improved statistical power compared with the more commonly used Tukey test (46).

Subjective hardness. For evaluating reliability of subjective assessments, an average of the second and third trials (first session) and an average of fifth and sixth trials (second session) were computed for each test item within each subject. Then, an intraclass correlation coefficient (ICC) between first and second session was computed for each test item. The method for computing ICC was based on a previous study (25). For testing the effect of food type on subjective hardness ratings, averages of the second, third, fifth and sixth trials were computed for each test item within each subject. One-way ANOVA and REGW-F test for post-hoc comparisons were used to test the effect of food type on subjective hardness ratings.

Interrelationship between objective and subjective hardness. It has been shown that there are semilogarithmic relationships between objective and subjective hardness for some foods (37, 44). To determine if a similar relationship was present for the items in this study, a Pearson’s correlation coefficient between the logarithm of objective hardness scores and subjective hardness ratings across the 12 test items was computed.

Study-2: Effect of the mixture ratio on hardness of wax cube. For testing the effect of the mixture ratio (80% Hi-Mic: SWC; 50% Hi-Mic: OWC; and 40% Hi-Mic: HWC) on subjective hardness ratings, averages of the second and third trials were computed for each test item within each subject. One-way ANOVA with REGW-F test for post-hoc comparisons were used to test the effect of the mixture ratio on objective hardness scores and subjective hardness ratings, respectively.

SPSS 11Æ5 was used for statistical analyses and P-values less than 0.05 were considered significant.

Results

Study-1: Comparisons wax cube to natural foods

Objective hardness. Means and standard deviations (SD) of objective hardness scores (N, newtons) for each item are shown in Table 2. Mean objective hardness scores ranged from 1.3 N for cream cheese to 82.5 N for raw carrot. One-way ANOVA found a significant effect of food type on objective hardness ($F = 119; P < 0.001$). Post-hoc tests (REGW-F) determined there were four subgroups which showed non-significant differences within each group ($P > 0.05$) (Table 2). Cream cheese, chewing gum, and boiled fish paste formed the first group of similar items with lowest hardness scores. The second (jelly, boiled beef and apple), third (wax cube, soft rice cracker and plain chocolate) and fourth (plain chocolate and peanut) groups showed increasing

**SPSS Japan Inc., Tokyo, Japan.**
hardness ratings. Hard rice cracker and raw carrot, the two items with the greatest hardness ratings, were not similar to any other items. The mean objective hardness score of the wax cube was significantly less than peanut and raw carrot, but significantly greater than chewing gum \((P < 0.05)\) (Table 2).

**Subjective hardness.** Intraclass correlation coefficients for test–retest reliability of subjective ratings of hardness were significant for all test items \((P < 0.001)\) and ranged from 0.68 for jelly to 0.93 for soft rice cracker. Mean subjective hardness ratings ranged from a mean of 4.8 for cream cheese to a mean of 78.4 for hard rice cracker on the 100 mm VAS (Table 3). One-way ANOVA found a significant effect of food type \((F = 67.4; P < 0.001)\). Post-hoc tests (REGW-F) determined there were three subgroups which showed non-significant difference within each group \((P > 0.05)\) (Table 3). Cream cheese was the item with lowest subjective hardness rating. Chewing gum, boiled fish paste and jelly formed the

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cream cheese(a)</td>
<td>1.3</td>
<td>0.2</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>2 Chewing gum(a)</td>
<td>1.4</td>
<td>0.1</td>
<td>NS</td>
<td>–</td>
<td>–</td>
<td>–</td>
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</tr>
<tr>
<td>3 Boiled fish paste(a)</td>
<td>3.0</td>
<td>0.1</td>
<td>NS</td>
<td>NS</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>4 Jelly(b)</td>
<td>15.0</td>
<td>1.4</td>
<td>*</td>
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<td>*</td>
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<tr>
<td>5 Boiled beef(b)</td>
<td>19.9</td>
<td>3.3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>–</td>
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<td>–</td>
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<tr>
<td>6 Apple(b)</td>
<td>23.1</td>
<td>5.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>7 Wax cube(c)</td>
<td>32.6</td>
<td>2.3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>8 Soft rice cracker(c)</td>
<td>34.7</td>
<td>8.9</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>9 Plain chocolate(c)</td>
<td>41.0</td>
<td>5.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>–</td>
<td>–</td>
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<tr>
<td>10 Peanut(d)</td>
<td>45.3</td>
<td>6.1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>11 Hard rice cracker</td>
<td>67.9</td>
<td>10.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>12 Raw carrot</td>
<td>82.5</td>
<td>19.5</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>–</td>
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</tr>
</tbody>
</table>

\(a, b, c, d\), Items with same character showed non-significant difference within each group \((P > 0.05)\).

\(a\), First group (cream cheese, chewing gum and boiled fish paste); \(b\), second group (jelly, boiled beef and apple); \(c\), (wax cube, soft rice cracker and plain chocolate); \(d\), forth group (plain chocolate and peanut).

\(*P < 0.05; **P < 0.001; NS, not significant.

\(†\)Original wax cube (50 weight % of Hi-Mic-1045).
first group of similar items. Boiled fish paste, jelly, and apple formed the second group. Wax cube, soft rice cracker, boiled beef, and plain chocolate formed the third group. Peanut, raw carrot and hard rice cracker were items were the items with highest hardness ratings, and were not similar to any other items. The mean subjective hardness rating of the wax cube was significantly less than either peanut or raw carrot, but significantly greater than chewing gum ($P < 0.05$) (Table 3).

**Interrelationship between objective and subjective hardness.** A significant positive correlation coefficient was seen between the logarithm of objective hardness scores and subjective hardness ratings ($r = 0.90$; $P < 0.001$) (Fig. 5).

**Study-2: Effect of the mixture ratio on hardness of wax cube**

Means and SDs of objective hardness score and subjective hardness rating for each wax cube (SWC, OWC and HWC) were presented in Table 4. ANOVA results indicate a significant effect of the mixture ratio on both objective hardness score ($F = 834.0$; $P < 0.001$) and subjective hardness rating ($F = 55.6$; $P < 0.001$). Post-hoc tests (REGW-F) show that all these wax cubes differed from each other for objective hardness scores and subjective hardness ratings (SWC < OWC < HWC; $P < 0.05$).

![Fig. 5. Relationship between logarithm of objective hardness score and subjective hardness rating ($r = 0.90$; $P < 0.001$).](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight % of Hi-Mic-1045</th>
<th>Objective hardness score (10 test pieces)*</th>
<th>Subjective hardness rating (n = 10)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softer wax cube (SWC)</td>
<td>80</td>
<td>20–3 (1.7)</td>
<td>13.5 (7.4)</td>
</tr>
<tr>
<td>Original wax cube (OWC)</td>
<td>50</td>
<td>32–6 (2.3)</td>
<td>45.5 (7.4)</td>
</tr>
<tr>
<td>Harder wax cube (HWC)</td>
<td>40</td>
<td>75–5 (4.7)</td>
<td>62.6 (15.0)</td>
</tr>
</tbody>
</table>

$^aP < 0.001$ (one-way ANOVA), SWC < OWC < HWC ($P < 0.05$, REGW-F test).

**Discussion**

Standardized masticatory performance tests (4, 9–16) have been used to assess the effectiveness of the stomatognathic system in particle selection and comminution of a food bolus. These tests primarily utilize tests items that fractionate and are representative of many difficult to chew items in a normal diet. However, other items in a common diet such as cheese and chewing gum do not readily fractionate and are subject to kneading and mixing before swallowing. Typically, these are softer foods and the chewing requirement may be quite different for this category of foods. In addition, changes to the dentition may effect the chewing of these soft foods differently than harder, fractionating foods. To evaluate chewing with these softer, more cohesive foods, a mixing ability test was developed employing a wax cube (24). However, the objective and subjective hardness in relation to other foods was not known. The results of current study demonstrated that both objective hardness scores and subjective hardness ratings of the wax cube were significantly lower than for peanut and raw carrot due to the different physical properties and structure.

The objective hardness scores obtained in this study cannot be compared with the results of other studies (30–33) because testing conditions and food characteristics have been found to impact objective hardness scores (29–32, 34, 35). However, the rankings of objective hardness scores of cream cheese, peanut and raw carrot agree with those obtained in previous studies.
High correlation was found between subjective hardness ratings and the logarithm of objective hardness scores \((r = 0.90)\). In spite of the high correlation, the rankings of mean objective hardness score for each item did not always agree with those of mean subjective hardness ratings. For example, the objective hardness score for boiled beef was ranked fifth, but was subjectively considered more hard (eighth). The rank in objective hardness score for hard rice cracker (11th) and raw carrot (12th) was reversed for subjective hardness. Possibly, previous experiences in their usual diet with similar items may have influenced the subjective assessments in this study. In the subjective assessments, a piece of each item approximately \(12 \times 12 \times 12\) mm in size was given to subjects, but larger pieces of hard rice crackers are more likely to be consumed in common form. Greater force may be required during biting with the larger pieces of hard rice cracker. Similarly, subjects may be more likely to consume beef that is more difficult to chew than the boiled beef in the current study, due to cooking style.

In this study, a compression rate of 40% was selected for the objective assessments of the items. In contrast, during chewing compression of 100% is sometimes achieved, with mandibular molars contacting maxillary molars. Unfortunately, the instrument used in the current study was unable to simulate this condition (100% compression rate) due to mechanical limitations. It has been shown that force-deformation characteristic of foods depends on compression rate \((34, 35)\). Thus, additional assessment of items with higher compression rates is necessary for complete characterization of the objective hardness.

Subjects, participating in this study, were not given any training sessions before assessment. Even with this untrained sample, reliability was relatively good as evidenced by the high ICCs. This suggests the subjective estimates of item/food hardness were consistent across subjects and may generalize well to similar populations.

It has been previously shown that objective hardness scores and subjective hardness ratings of some foods show a semilogarithmic relationship \((37, 44)\). This relationship was verified in the current study, where a strong positive correlation \((r = 0.90)\) between the logarithm of objective scores and subjective ratings of hardness were found, without using trained subjects. The shared experience with similar items in their diet may lead people to develop common internal ranking scales for food hardness. On the other hand, other studies have indicated that physiological parameters of masticatory muscle activity and mandibular movement achieve greater correlation than force/deformation scores with subjective food texture \((6, 42, 43)\). Since the objective assessment with force/deformation scores has some limitations, it would be desirable to simultaneously assess relationships between objective hardness scores, physiological parameters and the subjective assessment of hardness to clarify the relationships.

Study-2 found significant effects of the mixture ratio of hard and soft paraffin wax on objective hardness scores and subjective hardness ratings. This indicates hardness of the wax cube can be modified by changing the mixture ratio of hard and soft paraffin wax. Future studies are planned to evaluate the effect of hardness of the wax cube on index of food mixing ability. Possibly, different formulations of hardness may be more sensitive to variations in dentition status and prosthetic treatments.

Food texture is defined as a complex attribute composed of mechanical, geometrical and other perceptual characteristics \((27, 28)\). In this study, only hardness was evaluated among many mechanical characteristics of food texture. Other mechanical characteristics of the wax cube such as cohesiveness, elasticity, toughness and chewiness remain to be compared with the other test foods in further study. Within limitations of the study, it can be concluded that the wax cube used for the mixing ability test has softer texture compared with peanut and raw carrot.

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