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Relative contributions of occlusion, maximum bite force, and chewing cycle kinematics to masticatory performance

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Introduction: The purpose of this study was to explore the contributions of occlusion, maximum bite force, and chewing cycle kinematics to masticatory performance. **Methods:** A prospective cross-sectional study was performed on 30 subjects with Class I occlusion. Masticatory performance was measured with the test food Cuttersil (Heraeus Kulzer, South Bend, Ind) and the fractional-sieve technique. Blu-Mousse (Parkell Biomaterials, Farmingdale, NY) bite registrations were used to measure occlusal contact areas. The American Board of Orthodontics occlusal discrepancies were measured on the subjects' dental models. Maximum bite forces were recorded with a custom transducer, and 3-dimensional chewing cycle kinematics were tracked with an opto-electric computer system and Optotrak software (Northern Digital, Waterloo, Ontario, Canada). **Results:** Masticatory performance was most closely correlated with occlusal contact area, indicating larger contact areas in subjects with better performance. Occlusal contact area and occlusal discrepancies were also related to bite force and chewing cycle kinematics. Maximum bite force was positively related with masticatory performance. **Conclusions:** Although masticatory performance is related, both directly and indirectly, to a number of morphologic and functional factors, it is most closely related to occlusal factors. (Am J Orthod Dentofacial Orthop 2011;139:606-13)

The goal of orthodontic treatment is to improve the patient's life by enhancing jaw function and dentofacial esthetics.[1] In a recent survey, orthodontists and general practitioners rated good function, rather than morphology or esthetics, as the most important feature of an acceptable occlusion.[2] Impaired masticatory function can adversely affect quality of life.[3,4] Although orthodontists claim that improving masticatory function is a major goal, no standard assessment is routinely performed before or after treatment to determine whether improvements occur.

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Masticatory performance is the best overall measure of masticatory function.[5] It quantifies a patient's ability to break down food based on the size of food particles after a specified number of chewing cycles. Cuttersil (Heraeus Kulzer, South Bend, Ind), a condensation silicone impression material, is the test food of choice and is considered to be the standard for measuring masticatory performance.[6-11] Masticatory performance has been shown to be influenced by 3 main factors; teeth, masticatory muscle strength, and jaw movements. Although these factors have been studied individually, the relationships among them and their relative contributions to masticatory performance have yet to be determined.

It has been well established that masticatory performance is related to occlusion and occlusal contact areas. Subjects with malocclusion have lower masticatory performance than those with normal occlusion.[12-15] Occlusal areas of contact and near contact (ACNC) have been shown to be positively correlated with masticatory performance.[8,16-18]

Maximum bite force also affects masticatory performance. Hatch et al[19] showed that bite force was directly related to masticatory performance, although its impact was not as strong as the number of functional teeth.

Julien et al[8] found that maximum bite force, along with body size and occlusal contact area, explained 72% of the variation in masticatory performance among children and adults.

Whereas chewing cycle kinematics might be expected to influence masticatory performance, this association has not been well studied. Wilding and Lewin[20] showed that kinematic variables were significant determinants of chewing performance. It has also been shown that certain characteristics of muscle activity and jaw movement might be associated with improved masticatory performance.[21]

The purpose of this study was to explore the relative contributions of occlusion, occlusal contact areas, maximum bite forces, and chewing cycle kinematics to masticatory performance. To limit variation and spurious associations, the study was designed to focus on healthy, young adults with Class I occlusion.

MATERIAL AND METHODS

A prospective, cross-sectional study was designed to evaluate the relationship between occlusion, maximum bite force, chewing cycle kinematics, and masticatory performance. Thirty subjects (15 men, 15 women) were chosen from the students and staff at Baylor College of Dentistry in Dallas. The inclusion criteria included age between 22 and 32 years and Class I molar relationships. Class I occlusion was chosen because malocclusion has repeatedly been shown to be an important determinant of masticatory performance.[12-15] Subjects were excluded based on the following criteria: (1) missing teeth (excluding third molars), (2) symptoms of temporomandibular dysfunction including pain and crepitus, (3) active orthodontic or periodontic treatment, (4) full-coverage dental restorations or tooth replacements, and (5) more than 2 surface restorations on the right first premolars or right first molars. Each subject received an oral examination to assess occlusion, temporomandibular joint function, and state of dentition. Informed consent was obtained according to the guidelines for human research of the Institutional Review Board at Baylor College of Dentistry.

The artificial test food used in this study was Cuttersil, a condensation silicone impression material. An acrylic plastic template was used to standardize the size (20 mm in diameter and 5 mm thick) of the Cuttersil tablets. After hardening for at least 1 hour, the Cuttersil tablets were cut into quarters and packaged for each subject.[22] Each subject was given 2 quarter tablets per trial and instructed to chew naturally, on the right side only, for 30 chewing cycles.[23] After that, the subjects were instructed to stop chewing, expectorate the sample, and rinse with water until all particles were removed from the mouth. The procedure was repeated 7 times, until approximately 10 g of Cuttersil had been chewed and expectorated into a filter.

The chewed sample was dried in an oven for 1 hour at 80°C and then separated using a series of 7 sieves with mesh sizes of 5.6, 4.0, 2.8, 2.0, 0.85, 0.425, and 0.25 mm, stacked on a mechanical shaker and vibrated for 2 minutes.[24] Once the sample was separated, the contents of each sieve were weighed to the nearest 0.01 g.

Cumulative weight percentages (defined by the amount of the sample that could pass through each successive sieve) were calculated for each subject. From these percentages, the median particle size (MPS) was estimated by using the Rosin-Rammler equation.[9,25,26]

$$Q_w = 100\left[1 - 2^{-(x/x_{50})^b}\right]$$

where Q_w is the weight percentage of particles with a diameter smaller than x (maximum sieve aperture) and ^{b} is the broadness of the particle distribution. The MPS (x_{50}) is the aperture of a theoretical sieve through which 50% of the particles can pass.

To measure occlusal contact areas, 2 impressions of the right buccal segments were taken with Blu-Mousse, a vinyl polysiloxane impression material (Parkell Biomaterials, Farmingdale, NY). The impression material was expressed directly onto the mandibular occlusal table from the second molar to the first premolar. The subjects were then instructed to bite down firmly into maximum intercuspation and to hold that position for 30 seconds. To measure ACNC, the impressions were trimmed and optically scanned (mandibular occlusal surface facing down) on a Twain Pro flatbed scanner (Epson, Long Beach, Calif). A block of known length was included in every scan so that the area measurements could be calibrated to the actual size.

The software program UTHSCSA Image Tool (University of Texas Health Science Center, San Antonio) was used to manually trace the occlusal table area of the first and second premolars and molars. This software program automatically calculated the surface area of the occlusal table and the frequency distributions of pixels corresponding to each of the 256 gray scales (GS).

A step wedge of known thickness made of the Blu-Mousse impression material was scanned and used to calibrate the relationship between the 256 GS and the thickness of the occlusal registration. The thickness along the step wedge was measured with digital calipers (accurate to .001 μm). Based on the curve-fitting function in SPSS software (version 15, SPSS, Chicago, Ill), the relationship between the GS and the step-wedge thickness followed a curvilinear pattern ($R = 0.9855$, $P < 0.001$), expressed by the following formula:

$$thickness = 0.0147 + (.0005 * GS) + (.00000021 * GS^2)$$

Using the formula, we calculated 5ACNC values for each impression at 50-μm intervals. Each 50-μm increment was evaluated separately, and the increments were summed to estimate cumulative ACNC (cACNC). Data from the 2 impressions were averaged to provide estimates at or below 50, 100, 150, 200, and 250 μm for each subject.

Jeltrate (Dentsply Caulk, Milford, Del) alginate impressions were taken of each patient to create dental models. Six of the occlusal variables used by the American Board of Orthodontics objective grading system were measured on each model, including (1) alignment (A), (2) marginal ridges (MR), (3) buccolingual inclinations (BL), (4) posterior overjet (POJ), (5) occlusal contacts (OC), and (6) interproximal contacts (IPC).[27] Each score reflects the amount of deviation from an ideal occlusion. Each occlusal variable was measured twice and averaged.

Maximum bite force was measured with a custom transducer between the right first premolars and the right first molars. The subjects were given a practice trial at each site. Two maximum bite-force recordings were taken at the right first premolars, with 1 to 2 minutes of rest in between each trial, followed by 2 recordings at the right first molars. The maximum bite forces were recorded for 2 seconds at 100 Hz, by using Optotrak 3020 software (Northern Digital, Waterloo, Ontario, Canada). Using a real-time visual display, the operator (C.R.L.) started recording immediately after a steady maximum force level had been attained. The highest recorded value at each tooth position was used as the maximum bite force.

The chewing cycle kinematics were also recorded with Optotrak 3020 hardware and software. The system consists of 3 cameras that record 3-dimensional (3D) jaw movements (at 100 Hz) by using light-emitting diodes attached to the subject. The Optotrak system is accurate to 0.1 mm in the vertical and horizontal axes, and to 0.15 mm in depth. A single diode was taped to the subject's chin at pogonion to track mandibular movement. The subject also wore eyeglass frames that supported a rigid body consisting of 6 diodes; this recorded head movements, which the software eliminated from mandibular movements to derive pure jaw movements.

Each subject was positioned approximately 2 m from the Optotrak cameras. A reference position was obtained for each subject by using a digitizing probe to record the positions of the right and left tragus and orbitale; this oriented movements relative to the Frankfort horizontal plane. The subjects chewed a piece (2 g) of Wrigley's Orbit gum (WM Wrigley Jr, Peoria, Ill) to accustom themselves to the equipment before the kinematics were recorded.

The chewing cycle trials were recorded during the mastication of Cuttersil, as previously described. The subjects were instructed to begin with the Cuttersil on their tongue and with their teeth together in maximum intercuspation. There were 7 chewing sequences; each sequence consisted of 30 chews on the right side only. The investigator (C.R.L.) instructed the subject when to begin and counted the chewing cycles.

Chewing cycles were identified by using a custom computer program. The first cycle of each trial was discarded because it involved the initial positioning of the test food over the teeth. All cycles not within 0.5 to 2 seconds of duration or with vertical excursions of less than 3 mm were also excluded from the analyses. The program also ensured that the subjects chewed on the instructed side by evaluating lateral chin position during the closing phase. If this point was not located on the instructed side, relative to the starting frame, that cycle was eliminated.

Based on the acceptable cycles, the 10 most representative cycles of each trial were used for analyses.[28] For each acceptable cycle in a subject's chewing sequence, z-scores were computed for total cycle duration and maximum jaw excursive ranges in the lateral, vertical, and anteroposterior directions. The 4 z-scores were summed, and the 10 cycles with the lowest total z-scores were considered the most representative for that sequence. This process has been shown to reduce random within-subject variability by 20% to 76% without biasing the kinematic measurements.[29] Cycle duration, maximum cycle excursions, and maximum cycle velocity were calculated for each subject by averaging each measurement from the 10 most representative cycles.

The subjects' weights (in pounds) were recorded by using a calibrated scale, and their standing heights were measured (in inches) with a stadiometer.

Statistical analysis

Sex differences were evaluated with independent *t* tests. Pearson product moment correlations were used to determine the relationships between masticatory performance and the other variables. A stepwise multiple regression analysis was used to identify the explanatory variables most closely related to the performance measure. The level of statistical significance used was $P < 0.05$.

RESULTS

Significant sex differences were noted for height, weight, and several chewing cycle kinematic measurements, including opening and closing durations, lateral excursions to the working side, total excursions, and total 3D openings. No statistically significant sex differences were found for MPS, OC area, occlusal variable deviations, or maximum bite forces (Table I). The mean stature measurements were 71.7 ± 2.5 in for the men and 64.73 ± 1.9 in for the women. The mean weights for the men and women were 175.2 ± 21.2 and 138.13 ± 16.3 lbs, respectively.

MPS of the combined male and female subsamples was 1.86 ± 1.05 mm (range, 0.6-4.6 mm) (Table I). Areas of contact (0-50 μm) were larger than the other 50-μm intervals representing areas of near contact (51-100 μm, 101-150 μm, and so on) for both sexes. However, the total near-contact area (51-250 μm) was greater than the actual contact area (0-50 μm). ACNC 0-250 values were 68.7 ± 26.0 mm^2 for the men and 73.7 ± 34.9 mm^2 for the women. The occlusal discrepancies showed varying degrees of deviation from ideal. A and OC had the most deviations, whereas IPC and BL showed the least. Although the men tended to have higher bite forces than the women at the premolars (373.8 ± 102.6 vs 314.7 ± 96.5 N) and the molars (383.9 ± 102.3 vs 338.7 ±113.8 N), the differences were not statistically significant. The total durations of the chewing cycle were the same for the men and women (0.75 ± 0.07 and 0.75 ± 0.10 seconds, respectively). Men had significantly larger excursive movements and higher maximum velocities than did the women.

ACNC values were negatively related with MPS. Pearson product moment correlations showed negative correlations from –0.43 to –0.47 between ACNC and MPS. Performance was significantly related to ACNC between 50 and 150 μm; cACNC showed negative correlations from –0.26 to –0.37, with significant relationships for cACNC 0-150 and 0-200 μm (Table II).

No occlusal discrepancies from the objective grading system showed statistically significant correlations with masticatory performance (MPS). Importantly, OC was significantly correlated (range, –0.48 to –0.60) with all ACNC and cACNC values.

A statistically significant relationship was found between MPS and maximum premolar bite force ($R = -0.362$, $P = 0.027$). The greater the premolar bite forces, the smaller the MPS. However, no relationship was found between molar bite force and MPS.

Maximum bite forces were also related to the ACNC (Table III). All correlations were positive, indicating that greater bite forces were associated with greater contact areas. The maximum premolar bite force was significantly correlated to areas of contact at or below 50 μm ($R = 0.366$, $P = 0.047$). The maximum molar bite force showed statistically significant correlations with areas of contact (0-50 μm), areas of near contact (100-200 μm), and all ACNC values (Table III).

Table I. MPS, ACNC, occlusal discrepancies, bite forces, chewing cycle kinematics, and anthropometric measurements

	Men		*Women*		*Difference*
	Mean	*SD*	*Mean*	*SD*	P
MPS (mm)	1.9	1.1	1.8	1.1	0.64
ACNC (mm^2)					
Actual					
0–50 μm	23.8	9.6	23.4	15.8	0.94
51–100 μm	13.8	5.9	15.3	9.2	0.60
101–150 μm	8.9	3.6	10.1	3.9	0.40
151–200 μm	8.1	3.4	8.8	3.2	0.60
201–250 μm	14.1	6.6	16.1	6.0	0.39
cACNC					
0–50 μm	23.8	9.6	23.4	15.8	0.94
0–100 μm	37.6	14.8	38.7	23.8	0.88
0–150 μm	46.5	18.1	48.8	27.3	0.79
0–200 μm	54.6	21.2	57.6	30.1	0.76
0–250 μm	68.7	26.0	73.7	34.9	0.66
Occlusal discrepancies					
A	11.0	3.2	11.9	6.6	0.64
MR	4.3	1.7	4.0	1.7	0.63
BL	1.8	1.5	2.2	1.5	0.44
POJ	6.7	4.3	5.7	2.9	0.46
IPC	0.2	0.4	0.7	1.6	0.26
OC	11.6	8.7	10.8	9.0	0.81
Bite force (N)					
Premolar force	373.8	102.6	314.7	96.5	0.12
Molar force	383.9	102.3	338.7	113.8	0.27
Chewing cycle kinematics					
Duration (s)					
Opening	0.33	0.08	0.27	0.05	0.02
Closing	0.42	0.06	0.48	0.07	0.02
Total	0.75	0.08	0.75	0.10	0.89
Maximum excursions (mm)					
Vertical	10.31	2.30	8.94	2.34	0.11
Anteroposterior	6.59	2.19	5.73	1.76	0.25
Lateral	5.21	2.85	3.32	1.34	0.03
Working side	4.86	3.53	2.51	1.76	0.03
Balancing side	0.36	1.19	0.81	0.79	0.22
Total 3D distance	30.11	5.93	25.68	5.31	0.04
Total 3D opening	11.98	2.72	10.03	2.37	0.04
Maximum velocity (mm/s)					
Vertical	82.90	22.18	75.73	21.92	0.38
Anteroposterior	51.51	13.07	43.52	10.46	0.07
Lateral	42.54	24.73	28.91	12.96	0.07
Total 3D distance	97.97	28.17	84.84	22.45	0.17
Anthropometrics					
Height (in)	71.7	2.5	64.7	1.9	<0.001
Weight (lb)	175.2	21.2	138.1	16.3	<0.001

Statistically significant negative correlations were found between premolar and molar bite forces and IPC ($R = -0.383$, $P = 0.037$; $R = -0.421$, $P = 0.023$, respectively) and OC ($R = -0.393$, $P = 0.031$; $R = -0.516$, $P = 0.004$, respectively). The higher the bite force, the fewer the discrepancies for IPC and OC.

Table II. Pearson product moment correlations between MPS and ACNC and cACNC at various interocclusal thicknesses

	ACNC		cACNC	
Thickness	*R*	P	*R*	P
<50 μm	−0.26	0.16	−0.26	0.16
50–100 μm	−0.43	0.02	−0.34	0.07
100–150 μm	−0.47	0.01	−0.37	0.05
150–200 μm	−0.33	0.07	−0.37	0.04
200–250 μm	−0.14	0.43	−0.34	0.06

Table III. Pearson product moment correlations between maximum bite forces and ACNC at various interocclusal thicknesses

	Premolar force (N)		Molar force (N)	
Thickness	*R*	P	*R*	P
ACNC				
<50 μm	0.37	0.04	0.44	0.02
50–100 μm	0.25	0.18	0.29	0.13
100–150 μm	0.30	0.11	0.39	0.04
150–200 μm	0.31	0.10	0.40	0.03
200–250 μm	0.22	0.25	0.29	0.13
cACNC				
<50 μm	0.37	0.04	0.44	0.02
0–100 μm	0.34	0.07	0.40	0.03
0–150 μm	0.34	0.07	0.41	0.03
0–200 μm	0.34	0.07	0.42	0.03
0–250 μm	0.33	0.07	0.41	0.03

No significant correlations were found between any of the kinematic measurements and MPS. There were significant relationships between several kinematic measurements and height and weight (Table IV). Opening duration showed a weak positive correlation with body weight (R = 0.362, P = 0.049), and closing duration showed a weak negative correlation to body height and weight (R = –0.366, P = 0.047; R = –0.388, P = 0.034, respectively). Maximum vertical movements were positively related to weight (R = 0.374, P = 0.042); height and weight were correlated with maximum lateral, total 3D distance, and total 3D opening (Table IV). Maximum working-side movements showed significant positive correlations to height and weight (R = 0.461, P = 0.010; R = 0.507, P = 0.004, respectively). Lastly, maximum lateral velocity of the chewing cycle had positive correlations with height and weight (R = 0.479, P = 0.007; R = 0.431, P = 0.017, respectively).

Significant positive relationships were also identified between maximum posterior velocity and ACNC, as well as cACNC (Table V). Closing duration showed a weak positive correlation with cACNC 150-200 μm (R = 0.386, P = 0.035). Maximum vertical velocity was negatively correlated with POJ (R = –0.404, P = 0.027), and maximum anteroposterior velocity was negatively correlated with OC) (R = 0.424, P = 0.019). There was a moderate positive correlation between closing duration and molar bite force (R = 0.537, P = 0.003). There also were significant positive relationships between total duration with premolar and molar bite force (R = 0.512, P = 0.004; R = 0.507, P = 0.005, respectively).

The multiple regression analysis showed that 3 variables combined to explain 42% (R = 0.651, P = 0.003) of the variation in masticatory performance. The first variable was ACNC between 100 and 150 μm, explaining 19% of the variation. The second variable was A, a measure of occlusal discrepancy from the

Table IV. Pearson product moment correlations between chewing cycle kinematics and the anthropometrics

	Height (in)	*Weight (lbs)*
Duration (s)		
Opening	NS	0.362*
Closing	−0.366*	−0.388*
Total	NS	NS
Maximum excursions (mm)		
Vertical	NS	0.374*
Anteroposterior	NS	NS
Lateral	0.491†	0.540†
Total 3D distance	0.420*	0.445*
Total 3D opening	0.414*	0.463*
Working side	0.461*	0.507†
Balancing side	NS	NS
Maximum velocity (mm/s)		
Vertical	NS	NS
Anteroposterior	NS	NS
Lateral	0.479†	0.431*
Total	NS	NS

NS, Not statistically significant.
*Significant difference at P <0.05; †Significant difference at P <0.01.

Table V. Pearson product moment correlations between maximum anteroposterior velocity (mm/s) and ACNC and cACNC at various interocclusal thicknesses

Thickness	*R*	P	*Thickness*	*R*	P
ACNC			cACNC		
0–50 μm	−0.323	0.082	0–50 μm	−0.323	0.082
50–100 μm	−0.471	0.009	50–100 μm	−0.396	0.030
100–150 μm	−0.459	0.011	100–150 μm	−0.414	0.023
150–200 μm	−0.445	0.014	150–200 μm	−0.425	0.019
200–250 μm	−0.317	0.043	200–250 μm	−0.436	0.016

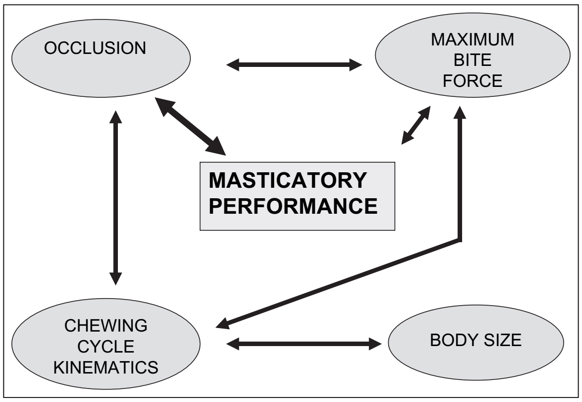

Fig. Summary of the significant interrelationships between various factors and masticatory performance.

objective grading system, explaining an additional 12% of variation. The last variable to enter the analysis was molar bite force, accounting for an additional 11% of the explained variation. The equation to estimate masticatory performance based on these 3 variables is as follows: masticatory performance = 5.24 – (0.093 * ACNC 100-150 μm) – (0.094 * A) – (0.004 * Molar Bite Force).

DISCUSSION

The MPS was smaller in this study than in other studies with the same test food. Owens et al[18] and English et al[14] reported MPS of 3.4 and 3.6 mm, respectively, for Class I subjects. Julien et al[8] found MPS to be 2.2 mm in males and 3.1 mm in females. However, the subjects in these studies chewed 3 quarter tablets of Cuttersil for 20 chewing cycles, whereas our subjects chewed 2 quarter tablets of Cuttersil for 30 chewing cycles, producing a MPS of 1.86 mm. It has been previously shown that MPS decreases with decreasing bolus size[6] and the number of chews.[30,31] Buschang et al[6] also showed that the smallest bolus size had the greatest between-subject variability. In this study, we purposefully tried to maximize variability in the primary outcome variable to increase the possibility of identifying functional interrelationships.

ACNC values were shown to be the most important determinants of masticatory performance. The negative correlations between MPS and the ACNC and cACNC demonstrate that the greater the OC area, the better the masticatory performance. Based on the correlations, ACNC values are more closely related to performance than areas of contact. This is also consistent with a study by Wilding and Lewin,[20] who reported that broad areas of intermediate OC (ie, near contact) appeared to contribute more to chewing efficiency in young adults than a few tight contact points. Owens et al[18] also found that performance is more closely related to near contacts than to contacts. Broader contact areas are thought to provide better occlusal support and allow elevator muscles to act more forcefully during chewing.[32] This also explains the association we observed between ACNC and bite forces. Greater occlusal stability is thought to keep the muscles fit and enable the masticatory system to work efficiently. The relationships between performance and OC are particularly important for orthodontists because a patient with a normal occlusion has significantly greater ACNC than one with a malocclusion.[18]

The occlusal contact discrepancy measurement on the models showed significant correlations with all ACNC and cACNC values, indicating that these 2 measures of contact were closely related. Also, both measurements showed significant relationships with bite force and chewing cycle kinematics. Associations might be expected, since they are measuring the same factor in different ways. This is important for orthodontists because it validates the OC discrepancy measurements used by the American Board of Orthodontics objective grading system.

Maximum bite force was the second factor that affected masticatory performance in this study. The greater the premolar bite forces, the better the performance. Julien et al[8] showed that, independent of height and weight, higher bite force contributed to increased masticatory performance. Hatch et al[19] also found maximum bite force to be a good predictor of performance in older subjects. Previous studies reported higher bite forces for men than women because of their larger muscles and jaw dimensions.[19,33,34] We found no significant sex differences, even though maximum bite forces were greater in the men then in the women. This suggests that our results were not sufficiently powerful to identify sex differences.

Greater bite forces were also associated with greater OC areas. The maximum premolar bite force showed significant positive relationships with the ACNC less than 50 μm; maximum molar bite force was related to several ACNC and all cACNC values. Significant positive correlations have also been reported between maximum bite force and the number of teeth in older adults.[33,35,36] Bakke et al[33] showed that the number of OC was a stronger determinant of muscle action and bite force than the number of teeth. There are 2 possible explanations for this relationship.[37] First, good occlusal support might allow for the development of stronger jaw elevator muscles and greater bite forces. Alternatively, stronger elevator muscles might create more OC. Tooth movements also appeared to play a role in this relationship.

Hidaka et al[38] found that the OC area doubled when the clenching level increased from 30% to 100%.

Although chewing cycle kinematics were not directly related to masticatory performance in this study, they showed indirect relationships via a number of other factors. For instance, larger subjects tended to have shorter closing durations, and greater and faster lateral excursions. Height and weight showed significant negative correlations with closing duration, indicating that larger subjects have faster closing movements. This might be related to increased muscle mass in larger people and a faster, more powerful, closing stroke. Greater lateral excursions among larger subjects might be explained because they have bigger jaws, resulting in a greater excursion for the same angular movement. Lastly, maximum lateral excursive velocity was greater in larger subjects; this could be related to larger muscles, producing faster jaw movements.

Several chewing cycle kinematic measurements were also related to occlusion. Greater posterior velocity was associated with greater OC area at all levels of ACNC and cACNC except ACNC less than 50 μm. OC discrepancies were also significantly related to posterior velocity. The less the discrepancy measured (ie, better occlusal contact), the faster the posterior velocity. Since greater OC area was related to better masticatory performance, it might be that, the better the occlusion fits together, the faster and more efficient the chewing cycle.

ACNC 150-200 μm was positively correlated with closing duration. This might indicate that, in subjects with better occlusion, vertical chopping movements (ie, shorter closing duration) are replaced by more lateral gliding (ie, longer closing duration) in the occlusal phase of the chewing cycle. Ahlgren[39] showed that subjects with malocclusion had predominantly chopping, reversed, and self-crossing chewing patterns when compared with subjects with normal occlusion.

The maximum premolar and molar bite forces showed significant positive correlations with total chewing cycle duration; closing duration also showed a significant positive correlation with maximum molar bite force. Since the closing jaw movement consists of 2 phases—the rapid phase before tooth contact, and the occlusal phase while the teeth are in contact—it is possible that a greater occlusal force is produced when a subject uses a slower, steadier chewing stroke and spends more time in the occlusal phase.

CONCLUSIONS

This study demonstrates that masticatory performance is influenced by many factors (Fig). Importantly, occlusion was clearly shown to be the key determinant affecting masticatory performance. Greater areas of contact and near contact provide better occlusal stability, allowing for more efficient masticatory function. Combined with tooth alignment and molar bite forces, areas of contact and near contact explained almost half of the individual variation in masticatory performance among young adults with Class I occlusion.

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