Occlusal Contact Area of Mandibular Teeth During Lateral Excursion

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Purpose: This study observed occlusal contacts and determined their areas on the mandibular teeth, especially the molars, during voluntary lateral excursions. **Materials and Methods:** Occlusal contact areas were estimated with a measurement system combining 3-D tracking of mandibular movements with 3-D digitization of tooth shape. Sixteen women with sound permanent dentitions participated. **Results:** At the intercuspal position, estimated occlusal contact areas of the first and second mandibular molars were on average 12.6 mm^2 and 9.0 mm^2, respectively. However, after 3.0 mm of lateral excursion, their areas were sharply reduced to 2.2 mm^2 and 1.5 mm^2 on the working side, and 0.4 mm^2 and 1.1 mm^2 on the nonworking side, respectively. **Conclusion:** These results suggest that the occlusal contact areas on working- and nonworking-side molars differ from each other as lateral excursion proceeds. *Int J Prosthodont 2004;17:72–76.*

Mandibular lateral excursion with occlusal contacts, which starts from the maximal intercuspal position (MICP), has received much attention because it is a part of the border movement and is thought by some to be crucial for the diagnosis and evaluation of restorative and reconstructive dental treatment.[1] Also, occlusal abnormality has been proposed as one of the etiologic factors of temporomandibular disorders.[2]

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Various aspects of voluntary lateral excursions have been studied, including mandibular kinematics,[3] the location and area of occlusal contacts,[4] and the frequency of the occlusal contacts.[5] However, it is still controversial whether nonworking (balancing) occlusal contacts should be eliminated in subjects with permanent dentitions. It has been proposed that nonfunctional interference might cause damage to the supporting tissues, jaw muscles, and temporomandibular joint (TMJ).[6] In contrast, others believe that occlusal contacts on the nonworking side are acceptable[7] or even beneficial,[8] as long as the nonworking-side contacts are lighter than the working-side contacts.[9] Additionally, certain types of nonworking-side contacts may protect the TMJ.[10]

Throughout lateral excursion, some maxillary and mandibular teeth are making contacts while, at the same time, others are separating. Therefore, observing the whole process in detail is quite difficult. To observe all changes in tooth contacts simultaneously, the authors developed a measurement system that combines recording of mandibular movements along all 6 degrees of freedom with a three-dimensional digitizer for tooth shape.[11] The present study addressed the following hypotheses: *(1)* nonworking-side contacts

Table 1 Frequency (%) of Occlusal Contact During Right and Left Lateral Excursion of All Mandibular Teeth on Both Working and Nonworking Sides (n = 16)

Position	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar
MICP	81	81	91	100	100	100	100
Working side							
1.0 mm	47	69	94	94	88	88	88
2.0 mm	47	69	94	81	66	78	69
3.0 mm	41	59	94	81	59	69	59
Nonworking side							
1.0 mm	50	28	31	41	63	72	78
2.0 mm	38	13	22	6	22	47	63
3.0 mm	31	13	16	3	13	31	63

MICP = maximal intercuspal position.

normally occur during voluntary lateral excursions; and *(2)* occlusal contact areas between working- and nonworking-side molars differ from each other during voluntary lateral excursions.

Materials and Methods

Sample and Experimental Task

Sixteen healthy, dentate women with permanent dentitions (none had third molars or large fillings including crowns and/or fixed partial dentures), aged between 20 and 28 years, were asked to participate in this study. For a subject to be included in this study, she had to meet the following criteria: *(1)* no pain during joint and muscle palpation, *(2)* no joint sounds, *(3)* a maximum opening greater than 40 mm, *(4)* a protrusion and laterotrusion greater than 7.0 mm, and *(5)* deviations or deflections less than 2.0 mm.[12] All subjects had Class I canine and molar relationships, normal overjet (< 4.0 mm) and overbite (< 4.0 mm), little crowding (< 4.0 mm), and rigid intercuspation of the teeth (ie, good occlusion), and no subjects had periodontal disease.

Prior to entering the study, informed consent (reviewed and approved by the ethics committee of the Faculty of Dental Science, Kyushu University, Fukuoka, Japan) was obtained. Voluntary left and right lateral border mandibular excursions from MICP with occlusal contacts were measured once for each subject. Thirty-two lateral excursions were measured in this study.

Measuring System

Details about the measuring system have been reported previously[11]; however, a brief description follows. Mandibular movement was measured using an optoelectronic analysis system (Trimet, Tokyo-Shizaisha) with 6 degrees of freedom. The accuracy of this optoelectronic instrument in bench tests is better than 0.19 mm.[13] Morphologic data from dental models were measured using a Tristation 400FE (Nikon). Using all recorded coordinates, a mathematic data mesh with intervals of 0.2 mm was constructed.

The pathways of the lateral excursions were divided into 0.1-mm intervals from MICP to 3.0 mm of excursion along the 3-D straight-line distance traveled by the medial tip of the mandibular left central incisor. This distance was defined as the "IP distance." The tooth row on the same side as the direction of excursion was referred to as the working side, and the opposite tooth row was referred to as the nonworking side. Distances from all points on the lower model to all points on the upper model were calculated, and the shortest distance for each point on the lower model was identified. The authors' previous results suggest that a clearance of less than 0.2 mm corresponds to occlusal contacts occurring in this system.[14] Therefore, the occlusal contact area of each tooth in the mandibular dentition in this study was calculated using this definition. The occlusal contact frequency, expressed as a percentage of 32 movements, was calculated for each mandibular tooth (Table 1).

Multilevel linear analysis was used to estimate the occlusal contact areas at each 1.0 mm of lateral excursion. A two-level model was used to estimate the mean and standard error of the mean for the occlusal contact areas. The significance of the fixed coefficients was determined by comparing the estimated mean to its standard error using the probability level $P < .05$. The two levels pertained to random variation between subjects and, within each subject, between right and left sides.[15,16]

Results

Examples of the changes of the occlusal contacts during a right lateral excursion in a single subject are shown in Fig 1. At MICP, this subject had occlusal

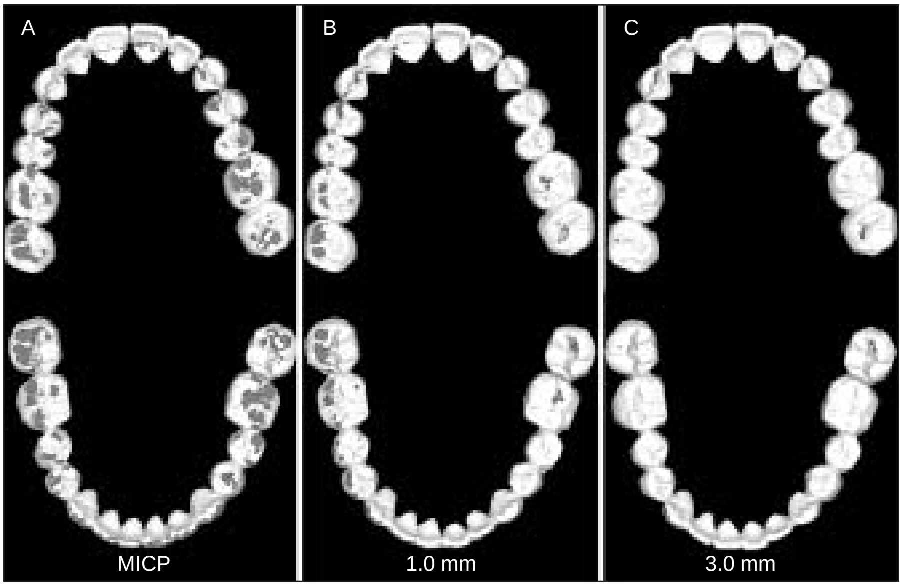

Fig 1 Example of computer-generated image of contacts during right lateral excursion at maximal intercuspal position *(MICP; A)*, 1.0-mm IP distance *(B)*, and 3.0-mm IP distance *(C)*. This figure shows the changes of the occlusal contact position and area during the lateral excursion.

contacts at every tooth on the maxilla and mandible. At the 1.0-mm IP distance, contact areas were observed on every tooth on the working side, but only on the first and second molars on the nonworking side. Occlusal contacts were considerably decreased everywhere, especially on the nonworking side. At the 3.0-mm IP distance, occlusal contacts were located only at the canine on the working side, but the nonworking-side contacts still remained on the second molar.

On the working side, every tooth except the central incisor maintained occlusal contacts until the 3.0-mm IP distance more than 60% of the time (Table 1). Occlusal contacts were observed on the canine 94% of the time and on the first premolar more than 80% of the time. On the other hand, as a rule, the percentages rapidly decreased on the nonworking side as the movement progressed. However, the second molar maintained contact more than 60% of the time, even at the 3.0-mm IP distance, and at this distance this percentage was higher than the working-side second molar.

As lateral excursion progressed, the total occlusal contact areas on the working side gradually decreased, showing an almost 70% decrease on the working side at the 3.0-mm IP distance (Fig 2a). Contact area on the nonworking side decreased at an even greater rate, showing an almost 70% decrease at the 1.0-mm IP distance. On the working side, the first molar contact area was much larger than the second molar contact area throughout the measured distance (Fig 2b). The difference in occlusal contact area between the first and second molars decreased as the lateral excursion advanced. On the nonworking side, the occlusal contact area of the first molar around MICP was also initially larger than that of the second molar. However, within the first 1.0 mm of movement, the contact areas of both teeth became almost equivalent, although both areas were much smaller than at MICP. Beyond the 1.0-mm IP distance, the nonworking-side second molar had larger contact areas than the nonworking-side first molar. Occlusal contact area of the nonworking-side second molar actually increased slightly, as contact areas of the other molars continued to decrease. The two molars on the same side had significant differences in contact area only at MICP on the working side (Table 2). In contrast, on the nonworking side, the first molar had significantly larger contact areas at MICP than did the second molar; however, this relationship was significantly reversed at the 3.0-mm IP distance.

Discussion

Our results demonstrated that the changes of the occlusal contacts and their areas during voluntary lateral excursion are dynamic. Watabe[17] calculated occlusal contact areas both at MICP and during lateral excursion in four subjects. Direct comparison with our estimates is difficult because that author defined the distance when occlusal contact occurred as less than 0.3 mm rather than less than 0.2 mm. In addition, he recorded contact area on the maxillary rather than the mandibular first molar. Yaffe and Ehrlich[18] examined the occlusal contact pattern of 72 normal subjects and reported that a type of group function in which more than two molars show occlusal contacts occurs 75.5% of the time on both sides at the 1.0-mm lateral movement position. Based on the frequency of the occlusal contacts, our results appear similar.

Nonworking-side contacts appear to be a normal part of voluntary lateral excursions because they

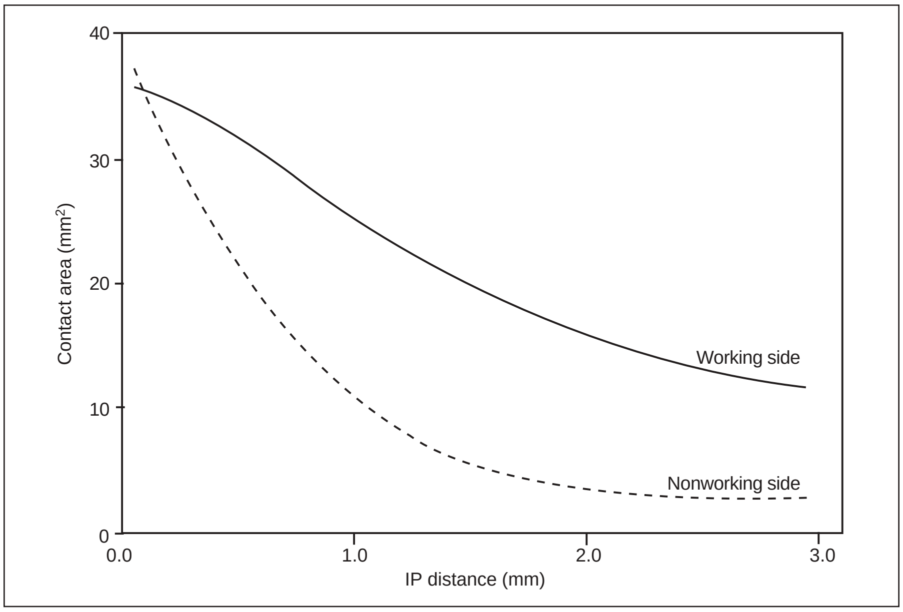

Fig 2a Comparison of sum of occlusal contact area for all mandibular teeth on working and nonworking sides.

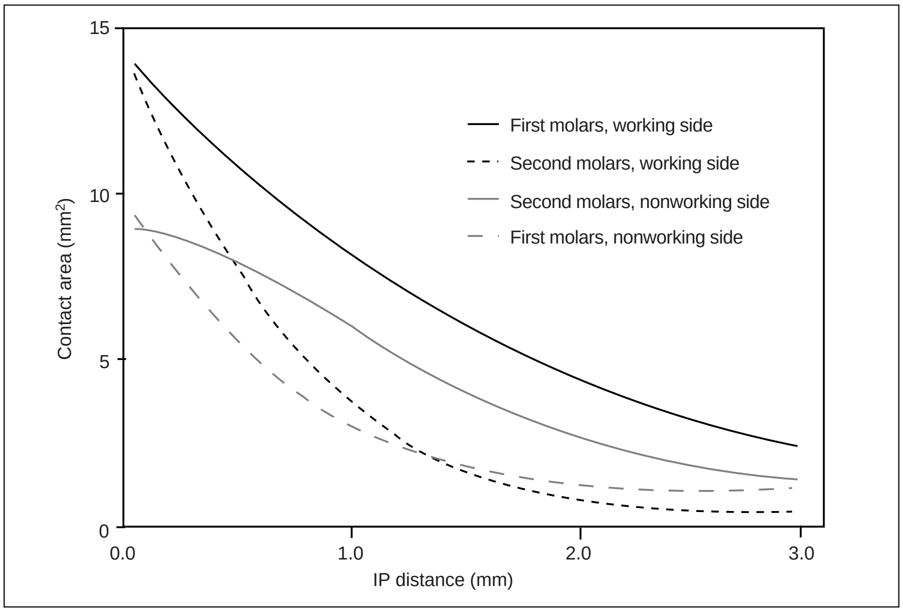

Fig 2b Comparison of sum of occlusal contact area for each molar during lateral excursions.

occur more than 60% of the time, at least on the second molar. This percentage is very close to earlier results.[19] In addition, occlusal contact areas between the working- and nonworking-side molars differ from each other during voluntary lateral excursions. The first molars on the working side had the largest occlusal contact area from the initiation of lateral excursion to the 3.0-mm IP distance. In contrast, the first molar on the nonworking side had the least occlusal contact area at the 3.0-mm IP distance.

From these results, it is obvious that voluntary lateral excursion is complex, with a constantly changing number of participating teeth. Numerous studies also have revealed that the occlusal contacts vary widely, even among subjects with morphologically sound occlusion.[2,18,20,21] Our results show this to be especially true in the early stages of lateral excursion because of the relatively large variation at the 1.0-mm IP distance compared to both MICP and further excursion distances.

Our next goal is to observe occlusal contact patterns during mastication. Future studies will help clarify the role of occlusal contact during normal function. The methods used in the present study should be able to differentiate between "nonworking-side interferences" and "functional occlusal contacts" on the nonworking side, as defined by Carlsson and Ingervall.[2] Such differentiation could be important when knowledge

Table 2 Fixed and Random Portion of Multilevel Models Describing Estimates of Means and Variances Between and Within Subjects (Between Sides) of Occlusal Contact Area (mm^2) at Each Position on Both Working and Nonworking Sides (n = 16)*

Estimate	Working side First molar	Working side Second molar	Working side All teeth	Nonworking side First molar	Nonworking side Second molar	Nonworking side All teeth
Occlusal contact area						
MICP	12.6 (0.8)[b]	9.0 (0.6)[b]	35.0 (1.9)	12.6 (0.8)[b]	9.0 (0.6)[b]	35.0 (1.9)
1.0 mm	8.0 (1.2)[a]	5.9 (0.8)[a]	24.9 (2.8)[a]	3.0 (0.8)[a]	2.8 (0.6)[a]	9.4 (2.3)[a]
2.0 mm	4.1 (0.8)[a]	2.8 (0.6)	15.9 (2.4)[a]	1.0 (0.4)[a]	1.6 (0.5)	4.3 (1.5)[a]
3.0 mm	2.2 (0.6)[a]	1.5 (0.4)	11.5 (1.6)[a]	0.4 (0.2)[a,b]	1.1 (0.3)[b]	2.7 (0.9)[a]
Variation between subjects						
MICP	3.0 (4.8)	1.0 (2.7)	23.6 (24.3)	3.0 (4.8)	1.0 (2.7)	23.6 (24.3)
1.0 mm	13.9 (8.9)	5.1 (5.8)	66.1 (51.0)	8.9 (3.7)	3.1 (2.2)	73.5 (30.0)
2.0 mm	6.6 (4.0)	0.9 (2.5)	62.4 (32.7)	2.2 (1.0)	2.2 (1.4)	29.8 (13.3)
3.0 mm	3.9 (2.2)	0.7 (0.9)	32.1 (15.1)	0.4 (0.2)	0.6 (0.5)	8.6 (4.3)
Variation within subject						
MICP	15.9 (5.6)	9.7 (3.4)	71.0 (25.0)	15.9 (5.6)	9.7 (3.4)	71.0 (25.0)
1.0 mm	19.0 (6.7)	27.7 (9.8)	127.3 (45.0)	2.9 (1.0)	5.3 (1.9)	21.3 (7.5)
2.0 mm	7.8 (2.8)	9.1 (3.2)	53.2 (18.8)	1.3 (0.5)	2.9 (1.0)	14.0 (5.0)
3.0 mm	4.1 (1.5)	3.0 (1.0)	19.2 (6.8)	0.3 (0.1)	1.3 (0.5)	6.3 (2.2)

*Standard error of the mean in parentheses.
[a]Difference between sides, $P < .05$.
[b]Difference between molars on the same side, $P < .05$.
MICP = maximal intercuspal position.

of the occlusal contact patterns plays a role in treatment planning.

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References

1. Adams SH, Zander HA. Functional tooth contacts in lateral and in centric occlusion. J Am Dent Assoc 1964;69:465–473.
2. Carlsson GE, Ingervall B. The dentition: Occlusal variations and problems. In: Mohl ND, Zarb GA, Carlsson GE, Rugh JD (eds). A Textbook of Occlusion. Chicago: Quintessence, 1988:209–226.
3. Ferrario VF, Sforza C, Miani A, Serrao G. Kinesiographic three-dimensional evaluation of mandibular border movements: A statistical study in a normal young nonpatient group. J Prosthet Dent 1992;68:672–676.
4. Hayashi T, Saitoh A, Ishioka K, Miyakawa M. A computerized system for analyzing occlusal relations during mandibular movements. Int J Prosthodont 1994;7:108–114.
5. Hochman N, Ehrlich J, Yaffe A. Tooth contact during dynamic lateral excursion in young adults. J Oral Rehabil 1995;22:221–224.
6. Magnusson T, Enbom L. Signs and symptoms of mandibular dysfunction after introduction of experimental balancing side interference. Acta Odontol Scand 1984;42:122–135.
7. Ingervall B, Hähner R, Kessi S. Pattern of tooth contacts in eccentric mandibular positions in young adults. J Prosthet Dent 1991;66:169–176.
8. Rugh JD, Ohrbach R. Occlusal parafunction. In: Mohl ND, Zarb GA, Carlsson GE, Rugh JD (eds). A Textbook of Occlusion. Chicago: Quintessence, 1988:249–261.
9. Ramfjord SP. Dysfunctional temporomandibular joint and muscle pain. J Prosthet Dent 1961;11:353–374.
10. Minagi S, Watanabe H, Sato T, Tsuru H. The relationship between balancing-side occlusal contact patterns and temporomandibular joint sounds in humans: Proposition of the concept of balancing-side protection. J Craniomandib Disord Facial Oral Pain 1990;4:251–256.
11. Okamoto A, Hayasaki H, Nishijima N, Iwase Y, Yamasaki Y, Nakata M. Occlusal contacts during lateral excursions in children with primary dentition. J Dent Res 2000;79:1890–1895.
12. Helkimo M. Studies on function and dysfunction of the masticatory system. II. Index for anamnestic and clinical dysfunction and occlusal stage. Swed Dent J 1974;67:101–121.
13. Hayashi T, Kurokawa M, Miyakawa M, et al. A high-resolution line sensor-based photostereometric system for measuring jaw movements in 6 degrees of freedom. Front Med Biol Eng 1994;6:171–186.
14. Hayasaki H, Nakata S, Nishijima N, et al. A calculation method for the range of occluding phase at the lower incisal point during chewing movements using the CMDME. J Oral Rehabil 1999;26:236–242.
15. Buschang PH, Throckmorton GS, Travers KH, Hayasaki H. Incisor and mandibular condylar movements of young adult females during maximum protrusion and laterotrusion of the jaw. Arch Oral Biol 2001;46:39–48.
16. Strenio J, Wisberg HI, Bryk A. Empirical Bayes estimation of individual growth curve parameters and their relationship to covariates. Biometrics 1983;39:71–86.
17. Watabe A. Changes of interocclusal contacts and clearance between opposing upper and lower molars during lateral excursions. J Jpn Prosthodont Soc 1995;39:517–529.
18. Yaffe A, Ehrlich J. The functional ranges of tooth contact in lateral gliding movements. J Prosthet Dent 1987;57:730–733.
19. Ingervall B. Tooth contacts on the functional and non-functional side in children and young adults. Arch Oral Biol 1972;17:191–200.
20. Korioth TWP. Analysis of working-side occlusal contacts. Int J Prosthodont 1990;3:349–355.
21. Woda A, Vigneron P, Kay D. Nonfunctional and functional occlusal contacts: A review of the literature. J Prosthet Dent 1979;42:335–341.