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CLINICAL STUDY

Functional occlusal patterns during lateral excursions in young adults

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ABSTRACT

Statement of problem. A valid system for assessing and classifying functional occlusion has not been established. The prevalence of anterior protected articulation is not known.

Purpose. The purpose of this study was to quantify the prevalence of various functional occlusal contact patterns, including anterior protected articulation, among dental students.

Material and methods. Occlusal contacts were examined during lateral excursions from the maximal intercuspal position to the canine-to-canine position in 100 young adults. A combination of 3 common clinical methods was used: a visual examination, articulating paper, and feedback from the participants.

Results. Data from 3 classification systems were analyzed: (1) Occlusal contacts on the working side only – canine protected articulation was present in 25% of laterotrusions; anterior protected articulation was present in 18.5% of laterotrusions. Group function was present in 56% of laterotrusions. Other schemes were present in 0.5% of laterotrusions. (2) Contacts on both the working and the nonworking side. (3) Contacts on the working and nonworking side during both right and left laterotrusion. Nonworking side contacts were present in 33% of the participants. Nonworking side interference was present in 1 participant.

Conclusions. The prevalence of anterior protected articulation found in this study was high enough to allow anterior protected articulation to be considered one of the fundamental working side occlusal contact patterns. More studies will be necessary to confirm this finding. (J Prosthet Dent 2015;113:571-577)

The criteria for ideal static occlusion,[1] based on the work of Angle[2] and Andrews,[3] have been generally accepted.[4] In contrast, which parameters constitute the ideal functional occlusion are subject to ongoing debate.[4,5] Epidemiologic studies exploring the prevalence of various occlusal contact patterns in sample populations contribute to the mosaic of knowledge in the field of functional occlusion.

Various classifications of functional occlusion have been used in epidemiologic studies on occlusal contact patterns during laterotrusion. They can be divided into 3 groups.

Certain authors[6-10] have classified functional occlusion during laterotrusion on the basis of a working side occlusal contact pattern only and ignored possible nonworking side contacts. Others[7,9,11-13] have assessed functional occlusion in a more complex manner, considering both working side and nonworking side contacts. The first type of classification system usually divides occlusal contact patterns during laterotrusion into 3 categories: canine protected articulation[1] (CPA), group function[1] (GF), and other. Instead of the term CPA, its synonyms (canine protection, canine guidance, canine-guided occlusion, cuspid-protected occlusion, and others) were used in the majority of reports. The pattern known as anterior protected articulation[1] (APA) was ignored in almost all the papers. Although APA is recognized in the *Glossary of Prosthodontic Terms* and in certain textbooks,[1,14] there are almost no data from epidemiologic studies on its prevalence. The second group of classification systems usually divides contact patterns during laterotrusion into 4 categories: CPA, GF, balanced occlusion (BO), and others. Once again, APA

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Clinical Implications

Studies of functional occlusion have suggested that clinicians have to choose only between canine protected articulation and group function when a change in the patient's laterotrusive occlusal contact pattern is indicated. This study supports the argument that anterior protected articulation is a relevant alternative.

was ignored in nearly[13] all the studies, and synonyms for CPA were used more than the term itself.

The third classification system was the most complex. The authors[4,15-18] did not classify right and left laterotrusion separately, but together as one entity in one individual. They reported the prevalence of certain functional patterns among the participants. The first and second type of systems reported a prevalence of functional patterns among the laterotrusions. The third type of classification system included categories such as bilateral balanced occlusion, unilateral balanced occlusion, canine-protected occlusion, mixed canine protected occlusion and group function, mixed balanced and group function, and others.

Criticism directed at all of these 3 classification systems can be found in the relevant literature.[8,13] There are more problems that need to be resolved. First, there are ambiguous definitions. Two differently defined schemes have often been presented under the same name of a particular pattern (such as, canine protection).[7,9,13] Some studies have considered canine protection to be contact between canines on the working side irrespective of the presence or absence of nonworking side contacts.[7,9] Other studies have considered canine protection to mean only the contact between the canines on the working side without any nonworking side contacts.[13] The reason is that the *Glossary of Prosthodontic Terms* provides no indication as to whether CPA, APA, and GF include situations with nonworking side contacts or not. Authors of studies have to decide on this issue themselves. Readers need to be careful and determine how these terms are defined in each study. The second issue is that various classification systems and differences in methodology make it difficult or impossible to compare studies. The third point is that the term *group function* encompasses a wide variety of working side lateral occlusal contacts, some of which might be considered an occlusal interference.[13] Certain studies have reported a high prevalence of the group function (86% if only the working side is considered[8]), suggesting that the classification would profit from dividing this large category into several smaller ones.[8] The last problem is the lack of data on the prevalence of APA.

Table 1. Type of occlusion and malocclusion

Type of Occlusion and Malocclusion	No. of Participants
Neutral	77
Distal	13
Mesial	0
Other	
Singular antagonism	6
Mixed neutral + distal	4
Horizontal overlap $\geq$ 6 mm	4
One or more incisors in crossbite	0
Vertical overlap $\geq$ 5 mm	26
Anterior open occlusal relationship in maximal intercuspation (one or more teeth)	24
Posterior open occlusal relationship in maximal intercuspation (one or more teeth)	6
Reverse articulation of one or more posterior teeth	12
Buccal nonocclusion of one or more posterior teeth	10
Crowding of maxillary anterior teeth	48
Crowding of mandibular anterior teeth	69

The purpose of the current study was to determine the prevalence of various functional occlusal contact patterns during laterotrusion among dental students. The assessment included APA, was detailed, and was comparable with all studies using any of the 3 aforementioned classification systems.

MATERIAL AND METHODS

Participants

One hundred dental students in their third year of studies at Palacký University in Olomouc, Czech Republic, participated in the study. There were 60 women and 40 men aged 20 to 32 years (average age 22.3 years, median 22). All the participants were either Czech or Slovak. The study was conducted over 2 successive academic years. In the first year, all the third year dental students (96) were asked to participate in the study and all agreed. However, 5 students were excluded because of ongoing orthodontic treatment and 1 was excluded because of illness. In the following year, 10 students were added to the studied population. They were chosen randomly (every eighth from an alphabetical list of all 89 third year dental students). The participants had well-preserved dentitions (Tables 1-3) with a few missing teeth or restorations involving a cusp or incisal edge. The number of teeth varied between 23 and 32 (median 29). Erosion and attrition/abrasion on the occlusal surfaces were relatively frequent, mostly in mild form. Prior orthodontic treatment was reported by 55% of the participants (65% of the women, 40% of the men). The study was approved by the Ethics Committee of Palacký University.

Recording of occlusal contacts

Occlusal contacts that occurred during laterotrusive movement from the maximal intercuspal position to the

Table 2. Number of missing teeth, restorations involving cusp or significant portion of incisal edge or occluding palatal surface, and crowns found in participants

	Maxilla			Mandible		
Teeth	**Missing Teeth (n)**	**Restorations (n)**	**Crowns (n)**	**Missing Teeth (n)**	**Restorations (n)**	**Crowns (n)**
Central incisors		10	2		1	
Lateral incisors	4	2	1	1		
Canines	1					
First premolars	18			12		
Second premolars	14		2	7	1	
First molars		11		1	17	1
Second molars		2		1	2	
Third molars	Not evaluated					

Table 3. Number of teeth with changes in occlusal surfaces due to erosion and attrition/abrasion

	Number of Affected Teeth in Maxilla						Number of Affected Teeth in Mandible					
	Total erosion + Attrition/Abrasion		Dominant cause				Total Erosion + Attrition/Abrasion		Dominant Cause			
			Erosion		Attrition/Abrasion				Erosion		Attrition/Abrasion	
Teeth	**Mild**	**Significant**	**BEWE 1**	**BEWE 2**	**Mild**	**Significant**	**Mild**	**Significant**	**Mild**	**Significant 2**	**Mild**	**Significant**
Central incisors	126	11	66	3	60	8	145	23	86	12	59	11
Lateral incisors	66	22	20		46	2	104	14	47	3	57	11
Canines	134	31	17	1	117	14	122	22	18	1	104	21
First premolars	58		19		39		57		6		51	
Second premolars	35		6		29		56		3		53	
First molars	124	1	20		104	1	155	14	49	9	106	5
Second molars	69		1		68		105	13	4	2	101	11
Third molars	Not evaluated											

BEWE, basic erosive wear examination, Bartlett et al, 2008.

canine-to-canine position were recorded on both the working and nonworking side during both right and left laterotrusion. Common clinical methods were used to detect occlusal contacts in 3 steps. The first assessment was conducted visually with the help of mirrors used for making intraoral photographs. For the second assessment, articulating paper (Bausch Progress 100 red and blue; Bausch) was used in 2 different ways. The teeth were dried and articulating paper was placed onto the maxillary teeth. Participants were asked to occlude in the maximal intercuspal position and then move their mandibular teeth to the right (left) side so that they would remain in contact with the maxillary teeth, to the canine-to-canine position. A darker colored articulating paper was then used, and the participants were asked to tap their teeth up into the maximal intercuspal position. The first color marked the laterotrusive movement. Another method was to apply articulating paper onto the maxillary teeth and close to the canine-to-canine position. The participants would then move their mandibular teeth so that they stayed in contact with the maxillary teeth to almost the maximal intercuspal position, without contacting the maximal intercuspal position. For the third assessment, the dental students were asked to state which teeth they felt in contact during the examination. In cases of discrepancy in the results of these 3 methods, the examination was repeated until the results agreed. In case canines were located outside the line of the arch, the ideal position of the canines rather than the real position was used for the examination. Examination of occlusal contacts was performed with participants seated in a dental chair. All the movements were guided by the participants themselves using a cosmetic mirror. One examiner (K.F.) performed all examinations, which were all done in the afternoon to avoid possible diurnal variations.

Additional data collection

Additional data (age, sex, history of orthodontic treatment) were collected with a questionnaire. Data concerning restorations and missing teeth were obtained from the protocols produced by the students themselves. Their accuracy was checked. In a few participants, these were examined clinically (by K.F.). Morphologic occlusion was evaluated with diagnostic casts, along with changes in the occlusal surfaces due to dental erosion and attrition/abrasion, or, in a few participants, clinically (by K.F.).

Statistical analysis

Statistical software (SPSS v15; SPSS Inc) was used. Women and men, nonorthodontic and postorthodontic participants, and right and left laterotrusion were compared on the prevalence of the occlusal contact

Table 4. Number of participants with defined occlusal contact pattern during right and left laterotrusion (first classification)

Movement	CPA	APA	RGF	Other	Total
Right laterotrusion (n)	25	24	51	0	100
Left laterotrusion (n)	25	13	61	1 NWSI	100
Total (n)	50	37	112	1	200
Total (%)	25	18.5	56	0.5	100

Prevalence of defined patterns among both laterotrusions.
CPA, canine protected articulation; APA, anterior protected articulation; RGF, rest of group function; NWSI, nonworking side interference.

Table 5. Number of participants with defined occlusal contact pattern (first classification)

	Left Laterotrusion (n)				
Right Laterotrusion (n)	CPA	APA	RGF	Other	Total
CPA	14	3	8	0	25
APA	6	8	10	0	24
RGF	5	2	43	1NWSI	51
Other	0	0	0	0	0
Total	25	13	61	1	100

CPA, canine protected articulation; APA, anterior protected articulation; RGF, rest of group function; NWSI, nonworking side interference.

patterns and on the prevalence of the nonworking side contacts. Symmetry of contact patterns was compared in men and women and in nonorthodontic and postorthodontic participants. The analysis of 2×2 contingency tables was carried out by the Fisher exact test. Contingency tables larger than 2×2 were analyzed with the Fisher-Freeman-Halton test (α=.05).

RESULTS

First classification

Under this classification, laterotrusions were classified on the basis of the working side occlusal contact pattern only. Possible nonworking side occlusal contacts were ignored. Four categories were used: CPA, APA, the rest of the group function (RGF), and other. For canine protected articulation (CPA), only canines on the working side were in contact during laterotrusion. For anterior protected articulation (APA), only anterior teeth on the working side were in contact. Instances of CPA were not included in APA. For the rest of the group function (RGF), a group of teeth on the working side was in contact. Instances of APA were not included in RGF. The sum of APA and RGF instances provided the prevalence of GF.

The most prevalent scheme was RGF (56% of the laterotrusions), followed by CPA (25%) and APA (18.5%). GF (APA and RGF) was present in 74.5% of the laterotrusions. Other schemes were present in 0.5% of the laterotrusions (Tables 4, 5). In 65% of the participants, the occlusal contact pattern during the right laterotrusion was the same as during the left laterotrusion (Table 5). No significant differences in the prevalence of occlusal contact patterns or in the number of symmetric patterns were found between women and men, nonorthodontic and postorthodontic participants, and right and left laterotrusion (Table 6).

Second classification

A more detailed classification was used in which not only the working side but also the nonworking side contacts were considered. Seven different occlusal contact patterns were recognized. These were CPA–, APA–, RGF–, CPA+, APA+, RGF+, and other. The minus sign represents the absence of nonworking side contacts and the plus sign for their presence.

The most common occlusal contact pattern during laterotrusion (Tables 7, 8) was RGF– (41% of laterotrusions). This was followed by CPA– (20.5% of laterotrusions) and APA– (15.5%). GF– (APA– and RGF–) was present in 56.5% of the laterotrusions. Laterotrusive occlusal contact patterns with nonworking side contact(s) were less frequent. RGF+ occurred in 15%, CPA+ in 4.5%, and APA+ in 3% of the laterotrusions. GF+ (APA+ and RGF+) was present in 18% of the laterotrusions. Balanced occlusion (sum of CPA+, APA+, and RGF+) was present in 22.5% of the laterotrusions. Other occlusal schemes occurred in 0.5% of the laterotrusions. In 51% of the participants, the occlusal contact pattern during the right laterotrusion did not differ from the pattern during the left laterotrusion (Table 8). The right and left laterotrusion differed in terms of the prevalence of RGF– and RGF+ (Table 7). This difference was statistically significant (P=.026, Table 6). No significant differences in the prevalence of occlusal contact patterns and in the number of symmetric patterns were found between women and men and nonorthodontic and postorthodontic participants (Table 6).

Third classification

In the most complex classification system, working and nonworking side contacts during both right and left laterotrusion were considered (Table 8). Seven different categories were used: bilateral CPA–, bilateral APA–, bilateral RGF–, mixed (CPA–/APA–, CPA–/RGF–, APA–/RGF–), unilateral balanced occlusion, bilateral balanced occlusion, and other. Authors of studies using a different categorization are able to compare their data by counting the prevalences of their categories themselves by using Table 8.

Bilateral CPA– was present in 11 participants, bilateral APA– in 7 participants, and bilateral RGF– in 23 participants. Mixed CPA–/APA–, CPA–/RGF–, or APA–/RGF– occurred in 25 participants. Unilateral balanced occlusion was found in 22 and bilateral balanced occlusion in 11 participants. Other scheme was present in 1 participant. No significant differences in the prevalence

Table 6. Statistical analysis of results

Classification System	Values	Compared Groups	Test	*P*
1	Prevalence of CPA, APA, RGF, other	Women, men	FFH	.457
		Postorthodontic , nonorthodontic	FFH	.684
		Right, left laterotrusion	FFH	.131
	Number of participants with symmetric and asymmetric contact patterns	Women, men	F	1.000
		Postorthodontic, nonorthodontic	F	.142
2	Prevalence of CPA– , APA– , RGF–, CPA+, APA+, RGF+, other.	Women, men	FFH	.678
		Postorthodontic, nonorthodontic	FFH	.809
		Right, left laterotrusion	FFH	.026*
	Number of participants with symmetric and asymmetric contact patterns	Women, men	F	.541
		Postorthodontic, nonorthodontic	F	.693
3	Prevalence of bilateral CPA– , bilateral APA– , bilateral RGF–, mixed, unilateral balanced occlusion, bilateral balanced occlusion, other	Women, men	FFH	.978
		Postorthodontic, nonorthodontic	FFH	.959
-	Prevalence of nonworking side contacts	Women, men	F	.863
		Nonorthodontic, postorthodontic	F	.735
		Right, left laterotrusion	F	.017*

CPA, canine protected articulation; APA, anterior protected articulation; RGF, rest of group function; NWSI, nonworking side interference; CPA– , APA– , RGF– working side patterns without nonworking side contacts; CPA+, APA+, RGF+ working side patterns with nonworking side contacts; FFH, Fisher-Freeman-Halton test; F, Fisher exact test.
*$P<.05$.

Table 7. Number of participants with defined occlusal contact pattern during right and left laterotrusion (second classification)

				NWSC				
Movement	**CPA–**	**APA–**	**RGF–**	**CPA+**	**APA+**	**RGF+**	**Other**	**Total**
Right laterotrusion (n)	20	19	31*		30*		0	100
				5	5	20*		
Left laterotrusion (n)	21	12	51*		15*		1 NWSI	100
				4	1	10*		
Total (n)	41	31	82		45		1 NWSI	200
				9	6	30		
Total (%)	20.5	15.5	41		22.5		0.5	100
				4.5	3	15		

CPA, canine protected articulation; APA, anterior protected articulation; RGF, rest of group function; NWSI, nonworking side interference; CPA– , APA– , RGF– working side patterns without nonworking side contacts; CPA+, APA+, RGF+ working side patterns with nonworking side contacts.
Prevalence of defined patterns among both laterotrusions.
*Difference between right and left laterotrusion was statistically significant ($P<.050$).

Table 8. Number of participants with defined occlusal contact pattern (second and third classification)

	Left Laterotrusion (n)							
Right Laterotrusion (n)	**CPA–**	**APA–**	**RGF–**	**CPA+**	**APA+**	**RGF+**	**Other**	**Total**
CPA–	11	3	5	0	0	1	0	20
APA–	4	7	7	1	0	0	0	19
RGF–	5	1	23	0	0	2	0	31
CPA+	0	0	2	3	0	0	0	5
APA+	1	0	2	0	1	1	0	5
RGF+	0	1	12	0	0	6	1 NWSI	20
Other	0	0	0	0	0	0	0	0
Total	21	12	51	4	1	10	1	100

CPA, canine protected articulation; APA, anterior protected articulation; RGF, rest of group function; NWSI, nonworking side interference; CPA– , APA– , RGF– working side patterns without nonworking side contacts; CPA+, APA+, RGF+ working side patterns with nonworking side contacts.

of occlusal contact patterns or in the number of symmetric patterns were found between women and men and nonorthodontic and postorthodontic participants (Table 6).

Additional findings

Nonworking side interference was defined as contact on the nonworking side, which prevents any occlusal contact on the working side. The prevalence of nonworking side interference was 1% of the participants. The interference was located on the nonworking side first molars, unilaterally. Nonworking side contacts[1] (NWSC) were present in 33% of the participants, in 22 participants unilaterally, and in 11 participants during both right and left laterotrusion. NWSC occurred in 22.5% of the laterotrusions.

The working side scheme most associated with NWSC was RGF. Associations of CPA and APA were similar, much lower than that of RGF (Table 7). NWSCs were mostly localized on the second molars. The number of both maxillary and mandibular teeth on the nonworking side that were in contact varied between 2 and 6 (median 2). During right laterotrusion, the prevalence of NWSC (30%) was higher than during left laterotrusion (15%). This difference was statistically significant ($P=.017$, Table 6). No significant differences in the prevalence of NWSC were found between women and men or between nonorthodontic and postorthodontic participants (Table 6).

DISCUSSION

The purpose of the study was to determine the prevalence of various laterotrusive occlusal schemes among dental students by using a unique analysis of data and

including APA. The participants in this study were young adults with well-preserved dentitions. The selection criteria were not as narrow as in certain studies,[4,6,8,9,12,13,15,17] but were relatively broad, as in other papers.[7,18] This study, in contrast to previous studies on functional occlusion, recorded the prevalence of dental erosion on occlusal surfaces among the participants.

The methods used to detect occlusal contacts were common clinical methods, similar to methods used in other studies.[10,18] Some studies used more sophisticated methods, such as dental floss and articulating paper,[6] articulating wax and dental floss,[17] shimstock,[4,8,9] silicone registration material,[15] alginate indices,[7] T-scan,[13] or articulating paper on articulated diagnostic casts.[12] A new approach in the current study was that it considered feedback from the participant as 1 method of detecting contacts. Although this is commonly used in clinical practice, no studies mention this method. Teeth are attached to the bone by periodontal ligaments, which allow light movement. Occlusal forces during laterotrusion are not distributed equally among the occluding teeth, as some of them bear a heavier load than others. It was not the goal of this third method to precisely record all (even slight) contacts; rather, it served as an additional check that the most important contacts were detected by the first 2 techniques.

Occlusal contacts were recorded during movement from the maximal intercuspal position to the canine-to-canine position, as in certain studies.[15-17] Some studies recorded contacts not during movement, but at certain defined positions.[4,6-9,12,13,18]

The most novel finding of this study was probably the prevalence of APA, which was present in 18.5% of the laterotrusions with the first classification system and in 15.5% of the laterotrusions with the second. APA– during both right and left laterotrusion (the third classification) was present in 7 participants. The prevalence of APA found in this study suggested that APA could be considered one of the basic working side occlusal contact patterns. Surprisingly, almost no data on the prevalence of APA are available from other studies. In a recent study,[13] APA– was present in 3% of the laterotrusions at the canine-to-canine position with the T-scan. Additional studies are needed to clarify the prevalence of APA.

A special classification of data was used to make this study comparable with most other papers. Nevertheless, differences in methodology among the studies hindered a larger comparison. As this study recorded contacts during movement from the maximal intercuspal position to the canine-to-canine position, only similar studies were eligible for comparison, that is, papers that recorded functional contacts during the same range of movement.[15-17] Additionally, studies that did not record contacts during movement, except at defined positions, but classified the laterotrusions on the basis of the total range of positions from the maximal intercuspal position to the canine-to-canine position[6,8,9] could be compared. Papers that recorded and classified laterotrusions at the defined position only (such as, at the canine-to-canine position) were excluded as being too dissimilar. With the first classification, the prevalence of CPA (25%) was higher than the results (12.5%, 10.5%, 10.1%) in other studies.[6,8,9] The prevalence of GF (74.5%), was lower than prevalences (87.5%, 86%, 84.5%) reported in other studies.[6,8,9] With the second classification, the prevalence of CPA– (20.5%) was higher than the results (0%, 9.3%) found by other authors.[6,8] The prevalence of GF– (56.5%) was higher than the results (3.1%, 45.3%) reported in other studies.[6,8] The prevalence of balanced occlusion (22.5%) was lower than the results (89.6%, 41.8%) reported in other studies.[6,8] With the third classification, the prevalence of bilateral CPA (11%) was higher than the results (1.3%, 1.4%, 8.9%) reported in other studies.[15-17] The prevalence of unilateral balanced occlusion (22%) was similar to the numbers (23.5%, 23.7%, 33.7%) reported in other studies.[15-17] The prevalence of bilateral balanced occlusion (11%) was lower than the prevalences (68.3%, 68.4%, 40.6%) reported in other papers.[15-17]

The occlusal contact pattern during right laterotrusion frequently differed from the pattern during left laterotrusion. This finding was also discovered by other authors.[13]

No statistically significant difference was found in the prevalence of occlusal contact patterns between men and women. This is in agreement with the findings of other authors.[13]

NWSC were present in 33% of the participants. Other studies reported a prevalence of 0 to 97%, median value 35%.[5] No statistically significant differences were found between men and women in the prevalence of NWSC, which is in conformity with the results of the majority of other studies.[5] Right and left laterotrusion differed in the prevalence of NWSC. The prevalence of nonworking side interferences was within the range of results from other studies.[5-7,13]

Certain findings of this study (the prevalence of APA) are limited by the fact that there are almost no other studies to compare them with. Future research should clarify the prevalence of APA and establish a valid system for examining and classifying occlusal contact patterns during laterotrusion.

CONCLUSIONS

This study described and analyzed the prevalence of various occlusal contact patterns during laterotrusion among dental students. The prevalence of APA found in

this study was sufficiently high to allow APA to be considered one of the basic working side occlusal contact patterns. Additional studies will be needed in order to confirm this finding.

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