The relationship between static occlusion and functional occlusion in a dental school population

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Classic work by Angle[1,2] and the relatively recent work of Andrews[3] have established accepted criteria for the optimal (ideal) morphologic relationship of the human dentition. The optimal, or ideal, functional occlusion type has not been so easily identified and has essentially eluded the dental profession. Several functional occlusion types have been recognized and/or advocated, such as balanced occlusion,[4,5] canine-protected occlusion,[6-13] group function occlusion,[14-18] flat plane (attritional) teeth occlusion,[19,20] and biologic (multi-varied) occlusion.[21] No one, single type functional occlusion has been found to predominate in nature. For example, D'Amico,[7] Ismail and Guevara,[22] and Scaife and Holt[23] all found a predominance of canine-protected occluson, while Beyron[18] and MacMillan[14] found a predominance of group function occlusion. Further, a high natural occurrence of balanced occlusion (i.e., possessing bilateral non-working contacts), was found in populations studied by Weinberg,[24] Yuodelis and Mann,[25] Ingervall,[26] Gazit and Liberman,[27] Sadowsky and BeGole,[28] Sadowsky and Polson,[29] Rinchuse and Sassouni,[30,31] Shefter and McFall,[32] deLaat and vanSteenberghe,[33] Ahlgren and Posselt,[34] Egermark-Eriksson et al.,[35] and Weinberg and Chastian.[36] Parenthetically, it is interesting to note that the type functional occlusion some have considered the "worst" type, i.e., balanced occlusion with its requisite non-working side contacts, may be the norm as regards prevalence, rather than the exception. Woda et al.[5] stated, "pure canine protection or pure group function rarely exists and balancing contacts seem to be the general rule in the populations of contemporary civilization."

Abstract

The relationship between static occlusion and functional occlusion was evaluated in 101 dental and dental hygiene students. The sample was selected from a population of 467 students who were enrolled at one dental school during the 1987-1988 academic year based upon the following criteria: age range 18 to 32 years; caucasian race; no prior orthodontic treatment; at least 28 natural teeth present; no occlusal adjustments; and no large restorations, crowns or bridges. Fifty-two (52) of the subjects possessed "normal" static occlusion, 26 had a Class I malocclusion, 16 were found to have a Class II malocclusion, and 7 had a Class III malocclusion. The majority (i.e., 75%) of the 101 subjects possessed non-working (balancing) functional contacts. Seventy-five (75) of the subjects possessed balanced occlusion, nine had canine-protected occlusion, nine possessed group function occlusion, and eight had mixed canine-protected/group functional occlusion. This study found no statistically significant relationship between static occlusion and functional occlusion, however, there was a trend for balanced occlusion to be more often associated with "normal" (ideal) static occlusion.

This manuscript was submitted September 1990.

Key Words

Static occlusion • Functional occlusion • Non-working (balancing) contacts

The acceptance of a functional occlusion type as the ideal has been based upon the notion that one functional occlusion predominates in nature and/or provides subjects (or is found associated) with the fewest TMD signs or symptoms and periodontal complaints. To help elucidate the role occlusion plays in the maintenance of health of the human stomatognathic system, varying functional occlusion types have been artificially produced in subjects with prosthetically restored or replaced teeth, and monitored via intra-oral telemetry[37] and/or electromyography.[38] The findings from these studies are inconclusive. Furthermore, the findings from provocation studies, in which functional occlusal interferences were produced in subjects, are also inconclusive.[39-44]

The superiority of one type of static or functional occlusion has not been unequivocally demonstrated by "hard" scientific data. Furthermore, data from epidemiological studies have led to the conclusion that morphological and/or functional occlusion variables play a minor role, or no role, in the etiology of TM disorders.[45-56] As Dolwich stated,[56] "although proposed occlusal factors appear to be mechanically logical, they are based on empirical, clinical observations and have not been proved by controlled studies." A cause-effect relationship has not been demonstrated between occlusion (i.e., morphologic or functional) and TM disorders.[57-62] At best, there may be an association between these two variables. In this respect, there are several anecdotal and correlational reports of a relationship between TMD signs and/or symptoms and Angle's malocclusions in general,[63,64] overbite,[35,63,65-69] overjet,[35,63,70,71] Angle Class II,[35,58,70,72-75] Angle Class III,[35] crossbite,[34,65,76,77] "tilted teeth,[78] loss of molar teeth,[79-82] and functional occlusal interferences.[69,83-92]

Few investigations have examined the possible relationship between static occlusion and functional occlusion. Scaife and Holt[23] studied the dentitions of 1 200 United States military trainees. Nine-hundred forty (940) of the subjects had Angle Class I occlusions. Canine-protected occlusion was found to be associated with Class II and then with Class I occlusions and was least associated with Class III malocclusions. The study by Scaife and Holt[23] was limited in that it did not distinguish between Class I malocclusions and "normal" (ideal) occlusions and did not identify or describe other functional occlusion types besides canine-protected occlusion.

Sadowsky and BeGole[28] examined 75 subjects with various types of Angle's malocclusions and found that 91% had balanced occlusion with non-working side eccentric contacts. Ingervall[26] studied 50 adults and 50 children with "normal" static occlusion and reported that at least 80% of the subjects possessed balanced occlusion. Rinchuse and Sassouni[30] found that 85% of 27 "normal" static occlusion subjects had balanced occlusion.

It is important for the orthodontist to know if a relationship exists between static occlusion and functional occlusion. If such a relationship does exist, the orthodontist must consider which type of functional occlusion is associated with which type of static occlusion. Of particular interest to the orthodontist would be the identification of the type of functional occlusion associated with "normal" (ideal) static occlusion since orthodontists direct their patient treatment toward achieving this type static occlusion.

The purpose of this investigation was to determine if a relationship exists between static occlusion and functional occlusion, and, if such a relationship exists, which type functional occlusion is associated with which type static occlusion.

Materials and methods

Sample

The population for this investigation consisted of 467 dental and dental hygiene students (i.e., the entire student body) enrolled at the University of Pittsburgh, School of Dental Medicine during the 1987-1988 academic year. Three-hundred twenty-four (324) of the students volunteered to complete a screening questionnaire and 159 were selected for the study based upon the following criteria: caucasian race; age range 18 to 32 years; at least 28 natural teeth present; no prior orthodontic treatment; no occlusal adjustment; and no large restorations, crowns, or bridges. Of the 159 qualified for the study, 101 elected to participate. Fifty-seven (57) of the subjects were male and 44 were female.

Methods of recording and measurement

Static and functional occlusions of each of the 101 subjects were assessed via a clinical examination with the subject in an upright seated position. Determination of static occlusion type was made from a visual inspection based on Angle's criteria.[1,2] Subjects' static occlusions were assigned to one of four discrete category types,[30] i.e., "normal" (ideal), Class I, Class II, or Class III. No distinction was made between Class II division 1 and Class II division 2 malocclusions.

Functional occlusal contacts were directly and visually determined with the aid of articulating wax and dental floss. Lateral functional excursions were generated by the subjects from "habitual centric" to the lateral cusp tip-to-cusp tip relationship[30] (i.e., usually about 3 mm lateral to habitual centric). Working and non-working side

Table 1
Functional occlusion types compared with the various static occlusion types for 101 dental school subjects

Static occlusion types according to Angle	Functional occlusion types: Canine protected	Group function	Mixed canine protected/group function	Unilateral balanced	Bilateral balanced	Total
Normal	3	5	5	16	23	52
Class I	4	1	1	11	9	26
Class II	1	2	2	6	5	16
Class III	1	1	0	1	4	7
Total	9	9	8	34	41	101

Chi-Square = 7.872 (df = 12)
∴ No significant difference ($P<0.05$)

contacts were recorded. The number and location of each lateral functional contact were recorded. In addition, the overall functional occlusion type was determined for each subject from the following discrete categories:[31]

1. *Canine-protected occlusion:* Canines in contact on the working side and no occlusal contacts on the non-working (balancing) side for either right or left lateral functional excursions.
2. *Group function occlusion:* Two or more teeth, other than the canines, in contact on the working side; and no non-working (balancing) contacts for either the right or left lateral functional excursions.
3. *Mixed canine protected/group function occlusion:* Canine-protected occlusion on one working side and group function occlusion on the other working side; no non-working (balancing) side contacts.
4. *Unilateral balanced occlusion:* Non-working (balancing) side contacts on either the right or left (but not both) lateral functional excursions. The functional occlusion that existed on the opposite side was free from non-working (balancing) side contacts.
5. *Bilateral balanced occlusion:* Non-working (balancing) side contacts on both right and left sides for both right and left lateral excursions. *Balanced occlusion referred to bilateral balanced occlusion and/or unilateral balanced occlusion.*

Reliability

Ten subjects were re-examined two weeks following the initial clinical exam. Intra-judge reliability was determined for the functional occlusion parameters by the use of percentage exact agreement for the two independent observations.

Method of data analysis

Chi-square tests ($P<0.05$) were used to statistically analyze the data.

Results

Reliability

Intra-judge determination of the exact number and location of the lateral functional occlusion contacts on the ten subjects was 81% agreement.

Static occlusion

Of the 101 subjects, 52 (52%) possessed "normal" (ideal) static occlusion. The distribution of the static occlusion type for the remaining subjects was: Class I — 26 (26%) subjects, Class II —16 (16%) subjects, and Class III — 7 (7%) subjects (Table 1).

Functional occlusion

The distribution of subjects according to functional occlusion type was: 9 (8.9%) subjects possessed canine-protected occlusion, 9 (8.9%) subjects had group function occlusion, 8 (7.9%) had mixed canine-protected/group function occlusion, 34 (33.7%) subjects possessed unilateral balanced occlusion, and 41 (40.6%) subjects had bilateral balanced occlusion (Table 1).

Static occlusion vs. functional occlusion

Bilateral balanced occlusion was the predominate functional occlusion type found for sub-

Table 2
Combined functional occlusion types compared with the various static occlusion types for 101 dental school subjects

Static occlusion types according to Angle	Combined functional occlusion types: Unilateral balanced and bilateral balanced	Combined functional occlusion types: Other (canine protected, group function & mixed canine protected/group function)	Total
Normal	39	13	52
Class I	20	6	62
Class II	11	5	16
Class III	5	2	7
Total	75	26	101

Chi-Square = .363 (df = 3)
∴ No significant difference ($P<0.05$)

jects with "normal" static occlusion (i.e., 23 subjects out of 52; 44.4%) and for subjects with Angle Class III malocclusions (4 subjects out of 7; 57.1%). Unilateral balanced occlusion was the predominate type functional occlusion for subjects with Angle Class I malocclusions (11 subjects out of 26; 42.3%) and Class III malocclusions (6 subjects out of 16; 42.3%) (Table 1). Canine-protected occlusion, group function occlusion, and mixed canine-protected/group function occlusion each occurred to a limited extent and was evident in all types of static occlusion with the exception that the "mixed" type functional occlusion did not occur with Class III malocclusions.

There was no statistically significant relationship between static occlusion and functional occlusion as evidenced by the chi-square analysis ($P<0.05$). There was, however, a trend for unilateral balanced occlusion and bilateral balanced occlusion to be associated more often with "normal" static occlusion; these types of functional occlusions were present in 75% of the subjects with "normal" static occlusion (Table 1).

Non-working (balancing) contacts

Most (i.e., 75) of the 101 subjects had non-working (balancing) side functional contacts (Tables 1, 2, & 3). Non-working side contacts are requisites of unilateral and bilateral balanced functional occlusion. Hence, 75 (74.3%) of the 101 subjects had one of these types of functional occlusions (Table 2). Non-working side contacts occurred most often on the second molars. Of 143 recorded non-working contacts, 104 (73.1%) occurred on the second molars. The first molars had the next highest frequency of non-working contacts.

The hypothesis that subjects with "normal" static occlusion have a greater number of non-working contacts than those with Angle's malocclusions was not supported by this research (Tables 2 & 3). All the various types of Angle's "normal" and malocclusions had a predominance of non-working contacts with no type having significantly greater numbers than the others (Tables 2 & 3).

Influences of working occlusion on non-working occlusion

The effect and influence of the type of working side functional occlusion on the number of non-working side contacts was statistically analyzed in this study. When only the canines contacted on the working side during lateral functional excursions, there were significantly fewer non-working side contacts, irrespective of static occlusion type, than there were when a number or group of teeth contacted on the working side (chi-square; $P<0.05$).

Discussion

The finding that 52 out of 101 subjects (51.1%) were found to have "normal" (ideal) static occlusion was surprising. However, Emrich et al.[93] and Goose et al.,[94] who studied American Caucasians and British Caucasians, respectively, also found a high natural occurrence of "normal" occlusion (i.e., 54% and 56%, respectively). The finding of the high percentage of subjects in this study with "normal" occlusion was probably

due to the exclusion of many potential Angle malocclusion subjects based upon their having had prior orthodontic treatment.

The finding that 74% of this study's sample had balanced occlusions and non-working side contacts compares favorably with several other studies. One must, however, be cautious about direct comparisons from one study to another because of the different methods employed to record and measure functional occlusion and the uniqueness of each study's sample and design. Nevertheless, Rinchuse and Sassouni[30] reported that 85.1% of 27 subjects with "normal" static occlusion had non-working eccentric contacts. Further, Ingervall[26] found that approximately 85% of 100 subjects had non-working side contacts. In addition, Sadowsky and BeGole[28] reported 89% of 75 subjects with various types of Angle malocclusions had non-working side contacts. Furthermore, deLaat and van-Steenberghe[33] found that 61% of 121 Belgian dental students with various Angle malocclusions had non-working contacts. Shefter and McFall[32] reported that 56% of 66 subjects with Angle malocclusions had non-working contacts. Also, Sadowsky and Polson[29] found that 45% of 111 subjects with Angle malocclusions had non-working contacts. Egermark-Eriksson et al.[35] reported that 34.5% of 238 subjects with Angle malocclusions had non-working contacts, and Ahlgren and Posselt[34] found that 34% of 120 subjects with Angle malocclusions had non-working contacts.

Although this study found no statistically significant relationship between static occlusion and functional occlusion, there was a trend for balanced occlusion to be more associated with "normal" static occlusion than with the other type functional occlusions. Seventy-five percent (75%) of the subjects in this study who possessed "normal" static occlusion had balanced occlusion. Rinchuse and Sassouni[31] reported that 86% of 27 subjects with "normal" static occlusion possessed balanced occlusion, and Ingervall[26] found balanced occlusion present in 88% of 50 children and 85% of 50 adults, who had "normal" static occlusion.

Rinchuse[30,31] hypothesized that populations with "normal" static occlusion would be more likely to possess non-working contacts and balanced occlusion than populations with Angle malocclusions, particularly Class II. In this regard, Rinchuse[30,31] showed a direct relationship between canine wear (i.e., attrition) and the number of non-working side contacts. That is, the more canine attrition the greater probability of finding non-working contacts. According to Rinchuse,[30,31] it is possible that subjects with "normal" static occlusion have a greater number of non-working contacts on lateral eccentric movements. They are, perhaps, more prone to canine attrition than subjects with Class II division 1 malocclusions in which the canine teeth demonstrate little canine attrition due possibly to their minimal contact during eccentric movements. Another explanation proposed[30,31] was that subjects with "normal" overbites could possibly have minimal vertical canine overlap and therefore less canine rise (i.e., disclusion) than subjects with deep overbites, in which case one might expect to find more non-working contacts.

Table 3
Frequency of non-working (balancing) contacts compared with the various static occlusion types

Numbers of patients with static occlusion types according to Angle	Number of non-working (balancing) contacts						
	0	1	2	3	4	5	Total
Normal	13	14	18	4	3	0	52
Class I	6	8	8	4	0	0	26
Class II	5	5	4	1	0	1	16
Class III	2	1	2	1	0	1	7
Total	26	28	32	10	3	2	101

Chi-Square = 13.909 (df = 15)
∴ No significant difference ($P<0.05$)

There are several possible explanations for the occurrence of the majority of non-working contacts on the second molars. The most obvious explanation would be that the typical location of the mandibular second molars in the ascending ramus of the mandible, which would necessarily elevate them (natural curve of spee), could account for the greater occurrence of non-working eccentric contacts for these teeth.

The present study was limited in that its sample was selective, i.e., dental school students. Further, because this study was causal-comparative with post-stratification of the data, an equal distribution of the subjects into each of the static and/or functional occlusion types was not probable and did not occur. Therefore, several of the static occlusion categories had few subjects representing them. Furthermore, the magnitude or severity of the static malocclusions was modest, at best, i.e., the Class II group had overjets less than 4 mm. Because this study's

population was dental students, perhaps those with severe malocclusions had been orthodontically treated. It is possible that static malocclusions of greater magnitude may demonstrate a relationship with functional occlusion.

Future studies should evaluate the static and functional occlusions in larger, homogenous and heterogenous populations. Static functional occlusion parameters should be investigated in relation to specific diagnostic categories (or subcategories) of TM disorders. Furthermore, samples should be matched so that there are equal numbers of subjects representing each of the various static occlusion types, i.e., "normal" occlusion and the various Angle malocclusions. An alternate approach may be to record millimeter variations from a Class I molar relationship in a continuous manner rather than have discrete static occlusion categories. This may better help delineate a possible relationship between static and functional occlusion, and also relationships with TMD signs/symptoms.

Conclusions

It is possible that an optimal functional occlusion type exists for each of the various static occlusion types and is compatible and harmonious with patients' stomatognathic systems. Furthermore, knowing the type of functional occlusion associated with "normal" (ideal) static occlusion may be of particular interest to the orthodontist. The present investigation failed to demonstrate a relationship between static occlusion and functional occlusion. This study did, however, find that for 101 subjects, 74% had balanced occlusion with non-working side eccentric contacts. Canine-protected occlusion and group function occlusion occurred only to a very limited extent.

Acknowledgements

The authors gratefully acknowledge the following, who contributed to this research: John Close, Hovhanness Shnorhokian, Hussein Zaki, Diane Karnavas, Kenneth Doleski and Douglas Smith.

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References

1. Angle, E.H.: Classification of malocclusion. Dent. Cosmos., 41:246-264, 1899.
2. Angle, E.H.: Malocclusion of teeth, 7th ed. Philadelphia: S.S. White Dental Mfg. Co., 1907.
3. Andrews, L.F.: The six keys to normal occlusion. Am. J. Orthod. Dentofac. Orthop., 62:296-309, 1972.
4. McLean, D.W.: Physiologic vs. pathologic occlusion. J. Am. Dent. Assoc., 25:1583-1594, 1938.
5. Woda, A., Vigneron, P., Kay, D.: Non-functional and functional occlusal contacts: a review of the literature. J. Prosth. Dent., 42:335-341, 1979.
6. Gysi, A.: Masticating efficiency in natural and artificial teeth. Dent. Digest, 21:74, 1915.
7. D'Amico, A.: The canine teeth: normal functional relation of the natural teeth of man. J. So. Calif. St. Dent. Assoc., 26:6-23, 49-60, 127-142, 175-182, 194-208, 239-241, 1958.
8. Kaplan, R.L.: Concepts of occlusion. Gnathology as a basis for a concept of occlusion. Dent. Clin. N. Am., 7:577-590, 1963.
9. Stuart, H., Stallard, C.E.: Concepts of occlusion — what kind of occlusion should recusped teeth be given? Dent. Clin. N. Am., 7:591-600, 1963.
10. Reynolds, J.M.: The organization of occlusion for natural teeth. J. Prosth. Dent., 26:56-67, 1971.
11. McAdam, D.B.: Tooth loading and cuspal guidance in canine and group function occlusions. J. Prosth. Dent., 35:283-290, 1976.
12. Lucia, V.O.: Modern gnathological concepts updated. Chicago: Quintessence Publishing Co. 189, 1983.
13. Schwartz, H.: Occlusal variations for reconstructing the natural dentition. J. Prosth. Dent., 55:101-105, 1986.
14. MacMillan, H.W.: Unilateral vs. bilateral balanced occlusion. J. Am. Dent. Assoc., 17:1207-1220, 1930.
15. Schuyler, C.H.: Factors contributing to traumatic occlusion. J. Prosth. Dent., 11:708-716, 1961.
16. Alexander, P.C.: Analysis of the cuspid protected occlusion. J. Prosth. Dent., 13:309-317, 1963.
17. Mann, A.W., Pankey, L.D.: Concepts of occlusion. The PM philosophy of occlusal rehabilitation. Dent. Clin. N. Am., 7:621-636, 1963.
18. Beyron, H.: Occlusal relation and mastication in Australian aborigines. Acta. Odonto. Scand., 22:597-778, 1964.
19. Begg, P.R.: Stone age man's dentition. Am. J. Orthod., Dentofac. Orthop., 40:298-312, 1954.
20. DeShields, R.W.: Gnathological considerations of a controversial nature. Dent. Survey. June:12-18, 1978.
21. Isaacson, D.: A biologic concept of occlusion. J. Prevent. Dent., 3:12-16, 1976.
22. Ismail, J., Guevara, P.: Personal communication of unpublished data. 1974.
23. Scaife, R.R., Holt, J.E.: Natural occurrence of cuspid guidance, J. Prosth. Dent., 22:225-229, 1969.
24. Weinberg, L.A.: The prevalence of tooth contact in eccentric movements of the jaws. J. Am. Dent. Assoc., 62: 402-406, 1961.
25. Yuodelis, R.A., Mann, M.V.: The prevalence and possible role of non-working contacts in periodontal disease. Perio., 3:219-333, 1965.
26. Ingervall, B.: Tooth contacts of the functional and non-functional side in children and young adults. Arch. Oral Bio., 17:191-200, 1972.
27. Gazit, E., Liebermann, M.A.: Occlusal contacts following orthodontic treatment. Angle Orthod., 55:316-320, 1985.
28. Sadowsky, C., BeGole, E.A.: Temporomandibular joint function and functional occlusion after orthodontic treatment. Am. J. Orthod. Dentofac. Orthop., 18:201-211, 1980.
29. Sadowsky, C., Polson, A.M.: Temporomandibular disorders and functional occlusion after orthodontic treatment: results of two long-term studies. Am. J. Orthod. Dentofac. Orthop., 86:386-390, 1984.
30. Rinchuse, D.J., Sassouni, V.: An evaluation of functional occlusal interferences in orthodontically treated subjects. Angle Orthod., 53:122-130, 1983.
31. Rinchuse, D.J., Sassouni, V.: An evaluation of eccentric occlusal contacts in orthodontically treated subjects. Am. J. Orthod. Dentofac. Orthop., 82:251-256, 1982.
32. Shefter, G.J., McFall, W.T.: Occlusal relations and periodontal status in human adults. J. Perio., 55:368-374, 1984.
33. deLaat, A., vanSteenberghe, D.: Occlusal relationships and temporomandibular joint dysfunction. Part I: epidemiological findings. J. Prosth. Dent., 54:835-842, 1985.

34. Ahlgren, J., Posselt, V.: Need of functional analysis and selective grinding in orthodontics. Acta. Odont. Scand., 25:3-13, 1963.
35. Egermark-Eriksson, I., Carlsson, G.E., Magnusson, T.: A long-term epidemiologic study of the relationship between occlusal factors and mandibular dysfunction in children and adolescents. J. Dent. Res., 66:67-71, 1987.
36. Weinberg, L.A., Chastain, J.K.: New TMJ clinical data and the implication on diagnosis and treatment. J. Am. Dent. Assoc., 120:305-311, 1990.
37. Butler, J.H., Zander, H.A.: Evaluation of two occlusal concepts. Parodent. Acad. Rev., 2:5-19, 1963.
38. Schaerer, P., Stalland, R., Zander, H.: Occlusal interferences and mastication: an electromyographic study. J. Prosth. Dent., 17:438-449, 1967.
39. Riise, C., Sheikholeslam, A.: The influence of experimental interfering occlusal contacts on the postural activity of the anterior temporal and masseter muscle in young adults. J. Oral Rehab., 9:419-425, 1982.
40. Randow, K., Carlsson, K., Edlund, J., Obery, T.: The effect of an occlusal interference on the masticatory system. Odont. Revy., 27:245-256, 1976.
41. Magnusson, T., Enbom, L.: Signs and symptoms of mandibular dysfunction after introduction of experimental balancing-side interferences. Acta. Odont. Scand., 42:129-135, 1984.
42. Rugh, J.D., Barghi, N., Drago, C.J.: Experimental occlusal discrepancies and nocturnal bruxism. J. Prosth. Dent., 51:548-553, 1984.
43. Plata, M., Barghi, N., Rey, R.: Clinical evaluation of induced occlusal disharmonies. J. Dent. Res., 61:203, 1982.
44. DeBoever, J.: Experimental occlusal balancing-contact interference and muscle activity. An electromyography study with permanently applied electrodes. Paradont., 23:59-69, 1969.
45. Mohlin, B. Ingervall, B., Thilander, B.: Relationship between malocclusion and mandibular dysfunction in Swedish men. Eur. J. Orthod., 2:229-237, 1980.
46. Graham, M.M., Buxbaum, J., Staling, L.M.: A study of occlusal relationships and the incidence of myofacial pain. J. Prosth. Dent., 47:549-555, 1982.
47. Bush, F.M.: Malocclusion, masticatory muscle, and temporomandibular joint tenderness. J. Dent. Res., 64:129-133, 1985.
48. Droukas, B., Lindee, C., Carlsson, G.E.: Occlusion and mandibular dysfunction: a clinical study of patients referred for functional disturbances of the masticatory system. J. Prosth. Dent., 53: 401-406, 1985.
49. Carlsson, G.E., Droukas, B.C.: Dental occlusion and the health of the masticatory system. J. Craniomand. Prac., 2:141-147, 1984.
50. Budtz-Jorgensen, E., Luan, W., Holm-Pedersen, P., Fejerskov, O.: Mandibular dysfunction related to dental, occlusal and prosthetic conditions in a selected elderly population. Gerodontics, 1:28-33, 1985.
51. Ramfjord, S.R.: Current concepts on the development of TMJ dysfunction. In: Carlson, D.S., McNamara, J.A., Ribbens, K.A. (eds). Developmental aspects of temporomandibular joint disorders. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series No. 16, 1985.
52. Meng, H.P., Dibbets, J.M.H., van dep Weele, Lth., Boering, G.: Symptoms of temporomandibular joint dysfunction and predisposing factors. J. Prosth. Dent., 57:215-222, 1987.
53. Zarb, G.: Development aspects of temporomandibular joint disorders. In: Carlson, D.S., McNamara, J.A., Ribbens, K.A. (eds). Developmental aspects of temporomandibular joint disorders. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series No. 16, 107, 1985.
54. Stringert, H.G., Worms, F.W.: Variations in skeletal dental patterns with structural and functional alterations of the temporomandibular joint: a preliminary report. Am. J. Orthod. Dentofac. Orthop., 89:285-297, 1986.
55. Pullinger, A.C., Solberg, W.K., Hollender, L., Peterson, A.: Relationship of mandibular condylar position to dental occlusal factors in an asymptomatic population. Am. J. Orthod. Dentofac. Orthop., 9:200-206, 1987.
56. Dolwich, F.M.: Diagnosis and etiology of internal derangements of the temporomandibular joint. In: The President's Conference on the examination, diagnosis and management of temporomandibular disorders. Chicago: ADA, 1983.
57. McLaughlin, R.P.: Malocclusion and the temporomandibular joint — a historical perspective. Angle Orthod., 85:185, 1988.
58. Griffiths, R.H.: Report of the President's Conference on examination, diagnosis and management of temporomandibular disorders. J. Am. Dent. Assoc., 106:75-77, 1983.

59. Rinchuse, D.J., Rinchuse, D.J.: The impact of the American Dental Association guidelines for the examination, diagnosis and management of temporomandibular disorders in orthodontic practices. Am. J. Orthod. Dentofac. Orthop., 83:518-522, 1983.
60. Rinchuse, D.J.: Counterpoint: preventing adverse effects on the temporomandibular joint through orthodontic treatment. Am. J. Orthod. Dentofac. Orthop., 91:500-504, 1987.
61. Storey, A.T.: Orthodontic treatment and temporomandibular function: the etiology of TM disorders. In: Carlson, D.S. (ed). Craniofacial growth theory and orthodontic treatment. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series No. 23. 106-107, 1990.
62. American Academy of Pediatric Dentistry, University of Texas Health Science Center at San Antonio Dental School. Treatment of temporomandibular disorders in children: summary statements and recommendations. J. Am. Dent. Assoc., 120:265-269, 1990.
63. Solberg, W.K., Bibb, C.A., Nordstrom, B.B., Hanson, T.L.: Malocclusion associated with temporomandibular joint changes in young adults at autopsy. Am. J. Orthod. Dentofac. Orthop., 89: 326-330, 1986.
64. Moyer, R.E.: The development of occlusion and temporomandibular joint disorders. In: Carlson, D.S., McNamara, J.A., Ribbens, K.A. (eds). Developmental aspects of temporomandibular joint disorders. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series, No. 16. 107, 1985.
65. Brandt, D.: Temporomandibular disorders and their association with morphologic malocclusion in children. In: Carlson, D.S., McNamara, J.A., Ribbens, K.A. (eds). Developmental aspects of temporomandibular joint disorders. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series, No. 16. 296-297, 1985.
66. Williamson, E.H.: Temporomandibular dysfunction in pretreatment adolescent patients. Am. J. Orthod. Dentofac. Orthop., 72:429-433, 1977.
67. Mohlin, B., Kopp, S.: A clinical study on the relationship between malocclusions, occlusal interferences and mandibular pain and dysfunction. Swed. Dent. J., 2:105-112, 1978.
68. Lieberman, M.A., Gazit, E., Fuchs, C., Lilos, P.: Mandibular dysfunction in 10-18 year old school children as related to morphological occlusion. J. Oral Rehabil., 12:209-214, 1985.
69. deLaat, A., vanSteenberghe, D., Lesaffe, E.: Occlusal relationship and temporomandibular joint dysfunction. Part II Correlation between occlusal and articular parameters and symptoms of TMJ dysfunction by means of stepwise logistic regression. J. Prosth. Dent., 55:116-121, 1986.
70. Nesbitt, B.A., Moyers, R.E., TenHave, T.: Adult temporomandibular joint disorder symptomatology and its association with childhood occlusal relations. In: Carlson, D.S., McNamara, J.A., Ribbens, K.A. (eds). Developmental aspects of temporomandibular joint disorders. University of Michigan: Center for Human Growth and Development, Craniofacial Growth Series, No. 16, 1985.
71. Riolo, M.L., Brandt, D., TenHave, T.: Association between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. Am. J. Orthod. Dentofac. Orthop., 92:467-477, 1987.
72. Ricketts, R.M.: Laminography in the diagnosis of temporomandibular joint disorders. J. Am. Dent. Assoc., 46: 620-648, 1953.
73. Perry, H.T. Jr.: Physiology of mandibular displacement. Angle Orthod., 30:51-60, 1960.
74. Thompson, J.R.: Abnormal function of the stomatognathic system and its orthodontic implications. Am. J. Orthod. Dentofac. Orthop., 48: 758-765, 1962.
75. Berry, D.C., Watkinson, A.C.: Mandibular dysfunction and incisor relationship. Brit. Dent. J., 144:74-77, 1978.
76. Egermark-Eriksson, I., Ingervall, B.: Anomalies of occlusion predisposing to occlusal interferences in children. Angle Orthod., 52:293-299, 1982.
77. Vanderos, A.: The relationship between craniomandibular dysfunction and malocclusion in white children with unilateral cleft lip and palate. J. Craniomand. Prac., 7:200-204, 1989.
78. Agerberg, A.: Occlusal and temporomandibular joint relations: a comparative study. J. Craniomand. Prac., 5:233-238, 1987.
79. Lubsen, C.C., Hansson, T.L., Nordstrom, B.B.: Histomorphometric analysis of cartilage and subchondral bone in mandibular condyles of young human adults at autopsy. Arch. Oral Biol., 30: 129-136, 1985.
80. Takeda, Y., Ishihara, H., Kobayashi, P.: Influence of occlusal interferences on nocturnal sleep and masseter muscle activity. J. Dent. Res. (Special Issue, AADR Abstract No. 561), 68, 1989.

81. Lundh, H., Westesson, P.L., Kopp, S.: A three-year follow-up of patients with reciprocal temporomandibular joint clicking. Oral Surg. Oral Med. Oral Pathol., 63:530, 1983.
82. Barghi, N., Agular, T., Martinez, C., Woodall, W.S., Maaskant, B.A.: Prevalence of types of temporomandibular joint clicking in subjects missing posterior teeth. J. Prosth. Dent., 57:617-620, 1987.
83. Nilner, M.: Prevalence of functional disturbances and disorders of the stomatognathic system in 15-18 year olds. Swed. Dent. J., 5:189-197, 1981.
84. Egermark-Eriksson, I.: Mandibular dysfunction in children and in individuals with dual bite. Swed. Dent. J., 6(Suppl. 10):9-20, 1982.
85. Mohlin, C., Carlsson, B., Friling, B., Hedgegard, B.: Frequency of symptoms of mandibular dysfunction in young Swedish men. J. Oral Rehab., 3:9-18, 1976.
86. Forssel, H., Kirveskari, T., Kangasniemi, P.: Response to occlusal treatment in headache patients previously treated to mock occlusal adjustment. Acta. Odontol. Scand., 45:77-80, 1987.
87. Kirveskari, P., leBell, Y., Salonen, M., Forssell, H., Grans, L.: Effect of elimination of occlusal interference on signs-symptoms of craniomandibular disorders in young adults. J. Oral Rehabil., 16:21-26, 1989.
88. Kirveskari, P., Alanen, P., Jamsa, T.: Association between craniomandibular disorders and occlusal interferences. J. Prosth. Dent., 62:66-69, 1989.
89. Krough-Poulsen, W.G., Olsson, A.: Occlusal disharmonies and dysfunction of the stomatognathic system. Dent. Clin. North Am., 627-635, 1966.
90. Egermark-Eriksson, I.: The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. Am. J. Orthod. Dentofac. Orthop., 83:187-194, 1983.
91. Cacchiotti, D., Bianchi, P., McNeil, C., Plesh, O.: Use of the mandibular position indicator in TMJ disorder diagnosis. J. Dent. Res. (Special Issue, AADR; Abstract No. 1674), 68, 1989.
92. Pullinger, A.C., Seligman, D.A., Solberg, W.K.: Temporomandibular disorders. Part II. Occlusal factors associated with temporomandibular joint tenderness and dysfunction. J. Prosth. Dent., 59:363-367, 1988.
93. Emrich, R.E., Brodie, A.G., Blayney, J.R.: Prevalence of Class I, Class II and Class III malocclusions (Angle) in a urban population: an epidemiological study. J. Dent. Res., 44:947-953, 1965.
94. Goose, D.H., Thomson, D.G., Winter, F.C.: Malocclusion in school children of West Midlands. Brit. Dent. J., 102:174-178, 1957.