A 6-YEAR FOLLOW-UP STUDY OF THE ORAL FUNCTION IN SHORTENED DENTAL ARCHES

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Een wetenschappelijke proeve op het gebied van de Medische Wetenschappen

PROEFSCHRIFT

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aan de Katholieke Universiteit Nijmegen,
volgens besluit van het College van Decanen
in het openbaar te verdedigen
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This study was part of the research programme "Dental Restorations and Biomaterials".
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Uit de vakgroep Orale Functieleer, afdeling Occlusie-opbouw (Hoofd: Prof. dr. A.F. Käyser).
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Contents

Chapter 1

General Introduction

1 General introduction

With the exception of developmental disorders, every individual is provided with a complete dentition, consisting of 28 (32) teeth or 14 (16) functional units. This occlusal system is not stable during life, as changes occur due to physiologic as well as pathologic processes, such as: wear, loss of alveolar bone height, caries, periodontal disease, and traumatic injuries. Without intervention in the form of preventive measures and restorative care, especially in high risk groups, a cumulation of changes takes place leading to an impaired occlusion with a reduced number of functional units.

A fundamental problem in restorative care for high risk subjects is the decision how many teeth should be saved and restored in order to guarantee satisfactory oral function. Preservation of complete dental arches may be technically possible, but should be weighed against factors such as: cost and real need for complete dental arches as well as the prognosis of high risk teeth. (Smith & Sheiham, 1980; Ettinger, 1984; Honkala, Rantala & Nyyssönen, 1984; Yule, 1984; Gordon & Sullivan, 1986; Pilot, 1986; Sheiham, 1991).

The traditional approach in prosthetic dentistry stressed the use of idealized morphological criteria and mechanically oriented concepts, such as in gnathology. According to many textbooks molar support should always be restored in order to prevent temporomandibular joint problems and occlusal instability. This compulsion to replace every missing tooth may lead to overtreatment (Lang, 1982), resulting in burdening the periodontal tissues. Based on clinical observation, Ramfjord stated in 1974 that: "Replacement of lost molars is a common source of iatrogenic periodontal disease, and should be avoided if requirements to aesthetics and functional stability can be satisfied without such replacements". The well-known restorative repair cycle (more than 50 % of dental restorative work consists of repairing previous restorations) is also partially a result of the traditional 28-tooth approach.

1.1 Criteria for a healthy occlusion

The prime aim of dental care is to maintain a natural functional dentition throughout life (Pilot, 1980), including all the social and biological functions, such as self-esteem, aesthetics, speech, chewing, taste and oral comfort (Sheiham, 1985, 1991). Since 1970 the (therapeutic) occlusal concepts have changed from dogmatically morphological and mechanical criteria towards a biological and functional orientation. The current criteria for a healthy or physiologic occlusion, as developed by Ramfjord & Ash (1983) and Mohl et al. (1988), reflect this shift clearly:

- absence of pathologic manifestations
- mandibular stability
- satisfactory function (aesthetics, chewing, etc.)
- variability in form and function
- adaptive capacity to changing situations

Variability in form and function means that the number of teeth may vary and may thus be less than 28. However, some teeth are indispensable, others are not.

As can be derived from Table 1-1, the anterior teeth and premolars together can - at least for several years - compensate the function of the molars (Käyser, 1981). There is no information, however, how durable this compensation is. Several epidemiological studies have shown a lack of correlation between the absence of posterior teeth and impaired oral function (Helφë & Helφë, 1978; Björn & Öwall, 1979; Imperiali, Grunder & Lang, 1984; Battistuzzi, Käyser & Kanters, 1987; Liedberg, Norlén & Öwall, 1991). As a result open spaces in the premolar and molar region were accepted to a high degree by the subjects, also in areas with a highly developed dental care system.

A cross-sectional study on 118 subjects with different dental arch lengths revealed that there is sufficient adaptive capacity to ensure acceptable oral function in shortened dental arches when the premolars are present (Käyser, 1981). This conclusion is supported by clinical observation and other studies (Meeuwissen, 1992).

Table 1-1. Assessment of the function of the different tooth types

	anteriors	premolars	molars
Biting	+	-	-
Chewing	-	+	+
Speech	+	-	-
Aesthetics	+	+	±
Stability of:			
- TMJ	+	+	+
- dental arch	+	+	+

+ = prime involvement
− = no or secondary involvement

1.2 The shortened dental arch concept

A shortened dental arch (SDA) is a dentition with a reduction of teeth starting posteriorly (Fig. 1-1).

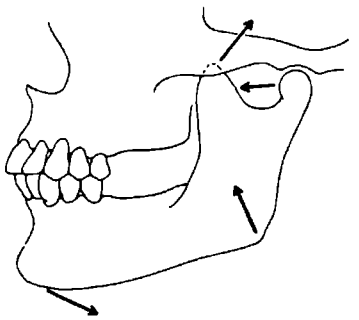

Fig. 1-1. A dental arch shortened to the second premolars (SDA).

In general, preference should be given to occlusions comprising complete dental arches. However, as stated before, adequate and complete restorative care of high risk groups may be technically possible, but is beyond the economic resources of many subjects or health care systems. This means that dental care strategies, aiming at preserving the natural dentition, should be increasingly cost-conscious. Choices have to be made as to which (occlusal) needs will be met (Ettinger, 1984; Pilot, 1986, Sheiham, 1991). With regard to dental diseases high risk teeth as well as high risk groups can be identified.

The molars have the highest plaque deposits (Shanley & Ahern, 1984; Silness & Rϕnstrand, 1988), and they are the most affected toothtype by caries (Katz et al, 1982; Dünninger & Naujoks, 1986; Arneberg, von der Fehr & Bjertness, 1988; Fure & Zickert, 1990; Willemsen et al, 1991). The molars are most frequently affected by both gingivitis as well as periodontitis (Brown, Oliver & Löe, 1989). They have the lowest bone height scores (Van Steenberghe, 1984; Salonen et al, 1991) and lowest attachment levels (Schei et al, 1959; Loë et al, 1978, Tal, 1984; Björn & Halling, 1987; Okamoto et al, 1988; Yoneyama et al, 1988). In other studies the molars are found to have a poor response to periodontal treatment or are designated as "looser sites" (McFall, 1982; Nordland et al, 1987; Loos et al, 1989; Lindhe et al, 1989; Wood, Greco & Mc Fall, 1989; Yokota et al, 1990; Schroer et al, 1991). Wennström, Papapanou & Gröhndahl, 1990, stated: "In recent reports on the pattern of destructive periodontal disease, it was shown that teeth in the posterior regions, particularly mandibular molars, are more likely to be extracted, and at an earlier stage, than anterior teeth". Consequently the molars are the most frequently removed tooth type (Jackson & Murray, 1972; Halse, Molven & Riorden, 1985; Cahen, Frank & Turlot, 1985; Meeuwissen & Eschen, 1985; Hand, Hunt & Kohout, 1991; Eckerbom, Magnusson & Martinsson, 1992). As a result, many studies demonstrated the continued retention of the anterior part of the dentition in contrast to the early loss of molars (Loftus et al, 1982; Österberg, Hedegård & Säter, 1984; Hugoson et al, 1986; Battistuzzi, Käyser & Peer, 1987; Toremalm & Öwall, 1988; Liedberg, Norlén & Öwall, 1991).

Several studies showed the large discrepancy between professionally assessed need and subjective treatment demand (Björn & Öwall, 1979; Imperali, Grunder & Lang, 1984), especially among elderly people (Tervonen, 1988; Vehkalahti & Paunio, 1988; Meeuwissen, 1992). This is the main reason why free-end removable partial dentures, replacing molars, are often not worn by the patient (Chandler & Brudvic, 1984; Toremalm & Öwall, 1988; Cowan et al, 1991). The discrepancy between need and demand for treatment is also present with respect to signs and symptoms of craniomandibular dysfunction, as only 7 % (Agerberg & Bergenholtz, 1989) or 3% (de Kanter et al, 1992) of the subjects reported that the symptoms were of such a magnitude that they had been, are, or will be seeking, advice from physicians or dentists.

In relation to age three levels of oral functional needs can be identified, which are expressed in needed pairs of occluding teeth or arch length (Table 1-2).

Table 1-2. Needed oral functional level in relation to age, expressed in minimum number of occluding pairs of teeth. (SDA=Shortened Dental Arch, ESDA=Extreme Shortened Dental Arch) (Käyser and Witter, 1985).

age	functional level		occluding pairs
20-50	I	optimal	12
40-80	II	suboptimal	10 (SDA)
70-100	III	minimal	8 (ESDA)

The first two defined levels (optimal and suboptimal) are based on clinical observation as well as findings from cross-sectional clinical studies. Suboptimal level II corresponds with 10 occluding pairs or a premolar dental arch (Fig. 1-1). More research is needed to assess what the term suboptimal function actually means.

Minimal functional level III is the level required at least for elderly people. This level is still mainly based on clinical observation, such as stated by Kjell Karlsen in 1973: "The number of teeth each individual needs cannot be ascertained by the dental profession. If a patient manages well with, for example, 8 or 10 anterior teeth - or even fewer - in each jaw, there is no reason to recommend prosthetic appliances". A recent clinical study tends to support this statement (Meeuwissen, 1992).

This thesis will concentrate on the functional capacity of the suboptimal level II or the premolar dental arch.

1.3 Functional changes related to shortened dental arches

In dentitions, where molars are absent, several structural- and functional changes are to be expected.

1.3.1 Stability of the dentition

Because of the reduction of occluding pairs of teeth in SDA, the occlusal forces on the remaining teeth may be supposed to be larger than in complete dental arches. Moreover, the premolars in SDA tend to migrate distally. This may lead to a decrease of the vertical dimension, resulting in an increased load on the anterior teeth. As a consequence many textbooks associate the SDA condition with anterior bite collapse. This collapse is characterized by an increasing overbite and interdental spacing or flaring of the anterior teeth.

In addition, as SDA have fewer teeth to perform the oral functions and to absorb the occlusal forces, it is suggested that this condition should cause intensified occlusal attrition and periodontal damage. Ramfjord & Ash (1983) stated that:"Whether abnormal occlusal forces injure normal periodontal structures or normal or excessive occlusal forces injure already weakened periodontal structures depends on: (1) the resistance and response of the tissue to the forces, and (2) the morphological features of the teeth, arches and the supporting structures that resist or modify the forces". Maybe the reduced number of remaining teeth in SDA cannot withstand the "abnormal or excessive occlusal forces", or on the

other hand, do not have the appropriate "morphological features of the teeth or arches", as molars are absent.

The question is raised whether a SDA is capable to withstand the occlusal forces for a prolonged period. If not, this condition should give rise to migration of teeth, occlusal instability and finally anterior bite collapse. Furthermore, intensified occlusal attrition and periodontal damage should be expected.

Chapters 2, 7, and 8 will deal with these items.

1.3.2 Changes in the temporomandibular joint

Some consequences of the absence of molar support for the functioning of the temporomandibular joint (TMJ) are mentioned in the literature (Mohl et al, 1988).

Firstly, the absence of molar support should result in overloading the TMJ-structures. Based on anatomical and histological evidence (the lack of both epiphyses and articular cartilage) it was argued that the TMJ is not a "weight-bearing" of "pressure bearing" joint and that no compressive loading occurs during function. More recent studies, applying mechanical analysis, demonstrated that stress to the TMJ-structures do occur under occlusal loads (Barbenel, 1974). So it is possible that the absence of molars may induce overloading of the TMJ (Carlsson, Kopp & Öberg, 1979). Secondly, a condylar displacement in SDA is considered to be responsible for craniomandibular dysfunction (CMD). In this "mechanical displacement concept" (De Boever, 1979), it is assumed that the absence of molars results in mandibular overclosure. As a result the condyles tend to deviate from their normal centric position in the TMJ.

Thirdly, SDA can cause alterations in function such as unilateral chewing, or chewing with the anterior teeth. Some studies (Boering, 1966; Franks, 1967; Agerberg & Carlssen, 1973) show a relation between unilateral function and signs and symptoms of CMD. Other studies (Österberg & Carlsson, 1979; Pond, Narghi & Barnwell, 1986) do not demonstrate such a relation.

Many authors claimed that neither a centric position nor a standard relation of the condyle to the articular surface of the temporal bone exists (De Boever, 1979). Besides, considering the current criteria for a healthy and physiological occlusion, it is more relevant whether the biomechanical stresses in a SDA condition exceed the limits of the adaptive capacity of the stomatognathic system (Mohl et al, 1988). This adaptive capacity consists of remodelling of the soft and hard tissues. Mesenchymale (chondrogene) cells are considered to be responsible for these remodelling activities, stimulated by changes in function and loading. These activities lead to deviation in form (DIF) (Solberg, Hansson & Nordström; 1985) and internal rearrangement (Ogus, 1987). Exceeding the limits of the adaptive capacity may provoke signs and symptoms of craniomandibular dysfunction, resulting in pain in or around the TMJ, noises or crepiting of the TMJ during function and restricted mobility of the mandible.

Chapters 3 and 9 will focus on the problems associated with craniomandibular dysfunction.

1.3.3 Changes in functional comfort

Traditionally the stomatognathic system was designated as masticatory system. This designation accentuated the importance of the capacity to reduce food. In modern society, where usually refined and soft or cooked food is eaten, the perceived oral comfort derived from the stomatognathic system is a more relevant item. It comprises more aspects than the capacity to reduce food particles. It includes also factors of social and communicational character. The most relevant items of oral comfort are the absence of pain and distress, the appreciation of the dental appearance and sufficient masticatory ability.

In many studies pulverization tests show that the masticatory performance or masticatory efficiency, which is the capacity to reduce testfood particles, is related linearly with the food platform area. Masticatory ability refers to the question wether the daily and normal food intake is felt to be hindered or not. It refers also to the question whether there is a shift in food selection due to dental impairment.

The results of most studies suggest that there is sufficient masticatory ability in reduced dentitions when at least 20 "well-distributed teeth" are present (Agerberg & Carlsson, 1981). Many studies in this respect accentuate the adaptive capacity of subjects with a reduced dentition, but also emphasize large interindividual differences. However, a SDA is a specific reduced dentition and there is little information available about the relation between a SDA and the masticatory ability. Aukes, Käyser & Felling (1988) found that subjects with a SDA did experience the texture of various foods somewhat different than subjects with complete dental arches.

The absence of molars, especially in the upper jaw, may influence the appearance. As aesthetics is an important item in functional comfort, the exact influence of missing molars should be investigated.

Chapters 5 and 9 will concentrate on aspects of oral comfort.

1.4 Clinical performance of removable partial dentures in shortened dental arches

In the past, traditional treatment concepts dictated the replacement of every missing tooth. For decades, in case of a SDA, a free-end RPD was the first treatment option. It was thought that a RPD replacing molars was necessary in order:

(i) to provide occlusal stability:
- to prevent anterior bite collapse
- to prevent overeruption of non-occluding teeth

(ii) to support the TMJ and consequently to prevent signs and symptoms of CMD,

(iii) to restore masticatory performance.

When using a functional or problem orientated approach in treatment planning, it is not quite evident which oral function has to be improved in case of a SDA comprising the anterior teeth and the premolars (Table 1-1). Furthermore, if any

oral function had to be improved it was not exactly clear to what level this improvement should reach (Käyser, Witter & Spanauf, 1987).

RPD's are considered to be appliances with potential negative side-effects. Only under favourable circumstances, which means providing regular recall in order to maintain proper oral and denture hygiene, caries, periodontal disease and other negative side-effects can be minimized (Berg, 1985). Besides, two additional problems are related to free-end RPD's. The first is the instability of the RPD due to resorption of the alveolar bone under the saddles (Bergman, 1987). The second problem is that, due to discomfort provoked by the RPD, subjects often decide not to wear the RPD any longer (Chandler & Brudvik, 1984, Cowan et al, 1991).

The clinical performance of free-end RPD's will be investigated in chapters 4, 5, 8 and 9.

1.5 Objectives and relevance of the study

The prime objective of this study is to investigate whether SDA, consisting of an anterior region and between 3-5 occluding posterior teeth can provide sufficient oral function for a prolonged period. Conclusions of a previous cross-sectional studie (Käyser, 1981) are still considered to be preliminary. This study will verify these preliminary findings by: (i) selecting a larger number of subjects with a SDA dental condition, and (ii) using a follow-up study design.
A derived aim is to investigate the performance of free-end RPD's in SDA.
The results of this study may influence restorative care in high risk patients as shown in Fig. 1-2.

When it is shown that reduced dentitions can function in an acceptable and durable way, goals for restorative treatment can be limited. The adventages are: less, and less complicated treatment, resulting in lower cost level, and accessibility for more patients.

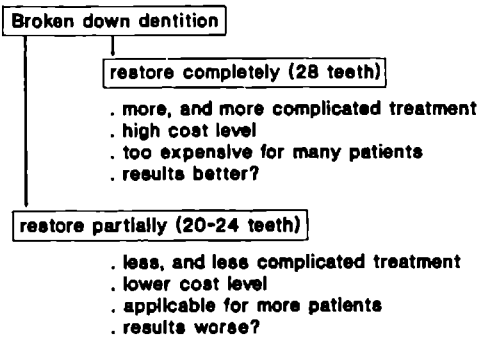

Fig. 1-2. Complete and limited treatment goals in restoring a broken-down dentition in high risk individuals.

1.6 Study design

Subjects with between three and five occlusal units were selected for this study. This group is referred to as the SDA group. Subjects with the same SDA condition extended with a free-end removable partial denture (in the lower jaw) are referred as the SDA + RPD group. A control- or reference group was selected consisting of subjects with complete dental arches. All subjects were selected from the patient population of the dental clinic of the University of Nijmegen. Further details are given in chapters 2 and 8.

As no criteria were applied to the periodontal condition, subjects with good as well as poor periodontal conditions were included.

Loss of teeth according to the natural history of the dentition does not follow a strict standard pattern, leaving pure SDA. Consequently subjects with a pure SDA (= a premolar arch) are scarse. For that reason the selection of the subjects required time and effort. Initially the SDA group consisted of 60 subjects. (Chapters 2 and 3). During the study this group was enlarged to 74 subjects.

Efforts were made to match the subjects according to age and gender. This attempt was not completely successful as women are overrepresented in the patient population in the Dental School and elderly subjects with complete natural dentitions were scarce.

Because changes in oral structures and function occur gradually, it was decided to investigate the subjects every three years, coinciding with the recall visits. A six-year follow-up was considered to be the minimum period for detecting possible changes longitudinally and to dectect differences in these changes between the three dental groups.

The structural changes and oral functions which were assumed to be affected by absent posterior teeth, were transformed in parameters. Table 1-3 shows the methods used in this study for measuring the different parameters.

Table 1-3. Investigated parameters and method used

parameter	method
- Occlusal stability	
Overbite	Ruler
Interdental spacing	Metal gauges
Occlusal contact	Occlusal stripe in IP
Attrition	Assessing occlusal wear
Alveolar bone height	Radiographs
- TMJ function	
Pain	Questionnaire
Noises/clicking	Questionnaire/palpation
MMO	Ruler
- Functional comfort	
Masticatory ability	Questionnaire
Aesthetics	Questionnaire
- (Para)functional activities	
Preferred chewing side	Questionnaire
Bruxism	Questionnaire/assessing occlusal wear

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Chapter 2

Migration of teeth in shortened dental arches

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Migration of teeth in shortened dental arches

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Summary

In shortened dental arches (SDA) the remaining premolars tend to migrate distally. This may lead to a decrease of the vertical dimension, resulting in an increased load on the anterior teeth. Consequently the number and intensity of the occlusal contacts between the front teeth increase. This may result in interdental spacing in the upper front region. In this study the pattern of migration of the teeth in subjects with SDA (n=60) is described. The SDA group is compared with subjects having complete dental arches (n=72). Although a systemic effect of SDA has been found on interdental spacing for subjects under 40 years of age, it is concluded that this migration is within acceptable levels.

Introduction

A shortened dental arch (SDA) is a dentition where the most posteriorly located teeth are missing, resulting in loss of molar support. This condition is seen frequently as molars are often lost by caries as well as periodontal disease (Halse, Molven & Riordan, 1985; Langer, Michman & Librach, 1975; Todd, Walker & Dodd, 1982). Shortening of dental arches may be considered in restorative treatment of high risk groups to concentrate the available resources on the more important front and premolar regions of the dental arch (Käyser & Witter, 1985). In implant therapy, such as in osseointegrated bridges, the concept of the SDA has been applied for many years, resulting in functionally acceptable occlusions (Haraldson, Carlsson & Ingervall, 1979; Lundqvist & Carlsson, 1983).

From a cross-sectional study of 118 subjects with different degrees of SDA it was concluded that when at least four occlusal units are left, preferably in a symmetrical position, sufficient oral function is maintained (Käyser, 1981). Some adaptive migration of the teeth took place but this was considered to be within an acceptable level. To verify this conclusion a study was made with three groups of subjects: a SDA group with between three and five occlusal units (Fig. 1), a SDA group where the dental arch was extended with free-end RPD, and a control group characterized by complete dental arches. These groups will be followed longitudinally. In this paper the SDA group is compared with the control group at the start of the observation with respect to migration of the teeth.

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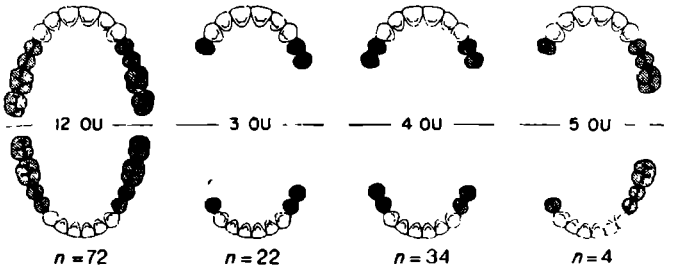

Fig. 1. Representation of the control group (n=72) and the SDA group (n=60). The variation of OU is shown in shaded teeth.

Subjects and methods

The subjects for this study were selected from the patients of the dental clinic of the University of Nijmegen. The SDA group (n=60) had to meet the following criteria:

(1) a remaining dental arch consisting of between three and five occlusal units (Fig. 1), one occlusal unit (OU) consisted of a pair of antagonistic premolars (one molar unit was considered equivalent to two OU);
(2) an acceptable anterior relation, which means that Angle Class III and extreme Class II anterior relations were excluded;
(3) no missing teeth in the remaining arches, unless replaced by bridges.

A control group (n=72) was selected meeting the same criteria, with the exception that these subjects had a complete dental arch. As it was expected that the age of the subjects might affect the variables to be measured, the subjects were divided into two age groups (Table 1). Table 2 shows the distribution of the duration of existence of the SDA.

It must be noted, that the SDA group, especially the elderly, had a high degree of restorative treatment, including crowns and bridges. As a rule these subjects had a dental history of caries and periodontal disease before acquiring a SDA. These conditions may have left an influence on the remaining dentition.

The following variables were measured in order to quantify the migration of the remaining teeth: occlusal contact, overbite, interdental contact or spacing and attrition.

The presence or absence of occlusal contact was measured with occlusal registration strips (Artus®, 13μm thick) (Halparin, Halparin & Norling, 1982),

Table 1. Distribution of the subjects with SDA (n=60) and the control group (n=72), according to age group and sex

					Age	
	Age group	n	Male	Female	Mean	SD
SDA	<40	33	16	17	31·0	4·6
SDA	≥40	27	9	18	51·2	9·2
Control	<40	46	24	22	29·9	5·2
Control	≥40	26	11	15	47·5	4·6

Table 2. Distribution of the subjects with SDA, according to the duration of existence of the SDA and the age group

Duration of existence of SDA (years)	Age <40 years		Age ≥40 years		Total
	n	%	*n*	%	
0–4	8	24	6	22	14
5–9	10	30	7	26	17
10–14	10	30	7	26	17
≥15	5	15	7	26	12
Total	33	100	27	100	60

while the subject closed into intercuspal position (IP). The overbite was measured in millimetres on incisors 11 and 41 (distance incisal edge 11 to incisal edge 41 in vertical direction). The interdental contact and spacing were measured with metal gauges (with thickness of 0·1, 0·5 and 1·0 mm) between the central incisors and between the present teeth of the right side of the mouth. Contact was judged to exist when the 0·1-mm gauge was obstructed in an interdental area. The following scores were used:

0: spacing<0·1 mm (contact);
1: spacing≥0·1 and <0·5 mm;
2: spacing≥0·5 and <1·0 mm;
3: spacing≥1·0 mm.

As the overbite may be decreased by progressive attrition, it was necessary to measure this phenomenon. This was done on the teeth of the right side of the mouth. The following attrition scale was used:

grade 0: no wear facets visible;
grade 1: facets in enamel, or in artificial crowns <1 mm (in diameter);
grade 2: facets in dentine, or in artificial crowns ≥1 mm and <2 mm;
grade 3: wear in secondary dentine, or in artificial crowns ≥2 mm.

With regard to the occlusal contacts, only the four incisors were taken into account for statistical analysis. The interdental contacts (or spacing) were expressed in an average score of spacing per region, using the above-mentioned scores. For each region a subject was excluded when two or all three interdental contacts could not be assessed (bridge or splinted crowns). With regard to the premolar regions it must be noted that in the case of a SDA with only one premolar present, the space 13–14 or 43–44 was scored as the average spacing. The average degree of attrition was calculated for both the upper and lower front teeth in the right side of the mouth and for the present premolars in the upper and lower right side together. Pairs of different groups of patients were compared by means of either the Wilcoxon two-sample test or, if the scores considered had the same value for more than 40% of the subjects, a test for equality of probabilities in a 2×2-table (χ^2-test with Yates's correction for continuity or in the case of low expected frequencies a two-sided version of Fisher's exact test).

Only P values smaller than 0·05 are mentioned specifically in considering the results of the statistical tests. It must be taken into account that four of the six possible two-by-two comparisons of four groups of patients were carried out and that these four tests were not independent. Therefore, only differences with $P<0·01$ are considered to be significant.

Results

The distribution of the occlusal contacts is presented in Fig. 2. Most contacts in the incisor region were found in subjects with SDA and who were over 40 years old, although neither the SDA effect nor the age effect are statistically significant when comparing the contacts of the four incisors. The results of the overbite are given in Table 3 and Fig. 3. Again there is no significant SDA or age effect. Figure 4 shows the distribution of the average score of the spacing per region. On the whole the SDA groups showed more spacing. In the upper and lower front regions the SDA subjects of age group under 40 years showed interdental contact less frequently than the controls of the same age group (exact Fisher test, $P=0·02$). Subjects under 40 years showed a significant effect of SDA on the interdental spacing between the lower premolars. Subjects with SDA showed significantly less interdental contact than the controls (Fisher's exact test, $P=0·005$). The differences were smaller in the upper premolars. In subjects over 40 years old the differences between the SDA and the control group were smaller and non-significant.

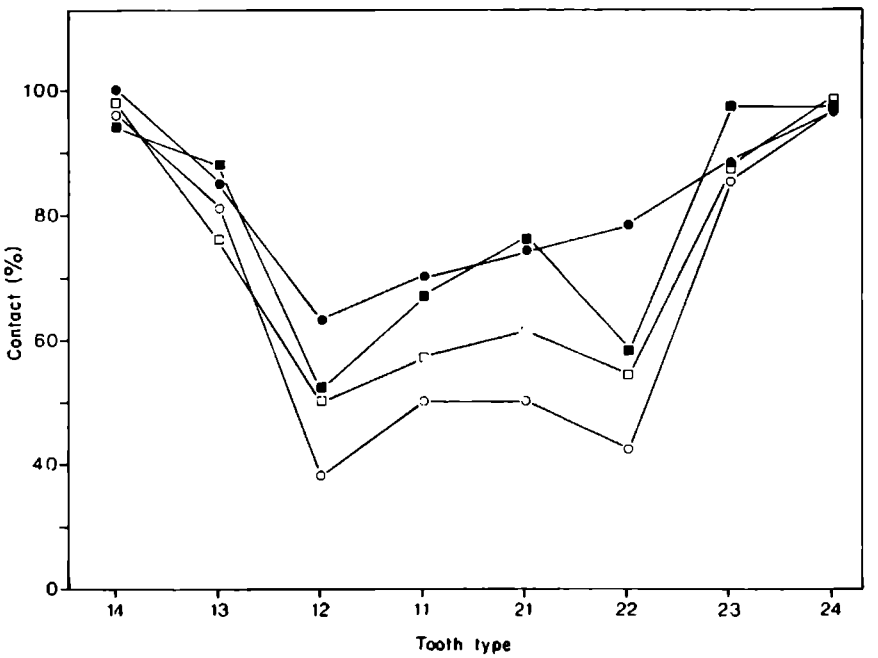

Fig. 2. Graphic representation of the occlusal contacts of the teeth 14 to 24. (■): SDA<40 years; (●): SDA≥40 years; (□): control<40 years; (○): control≥40 years.

Table 3. The mean overbite (mm) and s.d. for the four groups and the number of subjects with an overbite ≥6 mm

		Overbite		Overbite≥6 mm	
Group	*n*	Mean	s.d.	*n*	%
SDA<40	33	3·4	1·6	3	9·0
SDA≥40	27	3·3	1·5	3	11·1
Control<40	46	3·1	2·0	6	13·0
Control≥40	26	2·9	2·0	3	11·5

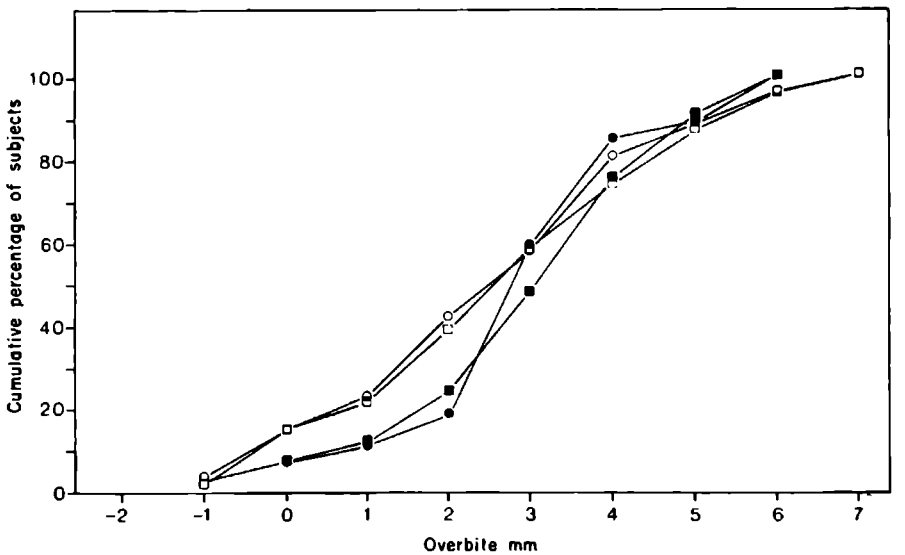

Fig. 3. Cumulative percentage of the subjects of the four groups with respect to the overbite. (■): SDA<40 years; (●): SDA≥40 years; (□): control<40 years; (○): control≥40 years.

The average degree of attrition per region is presented in Fig. 5. The control group above 40 years showed significantly more attrition into the dentine, than the SDA group above 40 years. This was significant for the upper front teeth (P=0·009, Wilcoxon two-sample test). Comparing the control subjects above 40 years with those under 40 years disclosed an age effect. The older subjects showed more attrition on the upper front teeth (P=0·023), more on the lower front teeth (P=0·005) and more on the premolars (P=0·016, Wilcoxon two-sample test). None of the subjects scored attrition into secondary dentine.

Discussion

The results show that in IP there is just a trend to more occlusal contact of the front teeth in subjects with SDA. Riise (1982) found a smaller number of occlusal contacts at low pressure than at hard pressure. In this study the subjects were asked to close the mouth without any further instruction.

Bohl (1974) found a considerably lower percentage of occlusal contacts in IP for the maxillary cuspids in subjects with complete natural Angle Class I

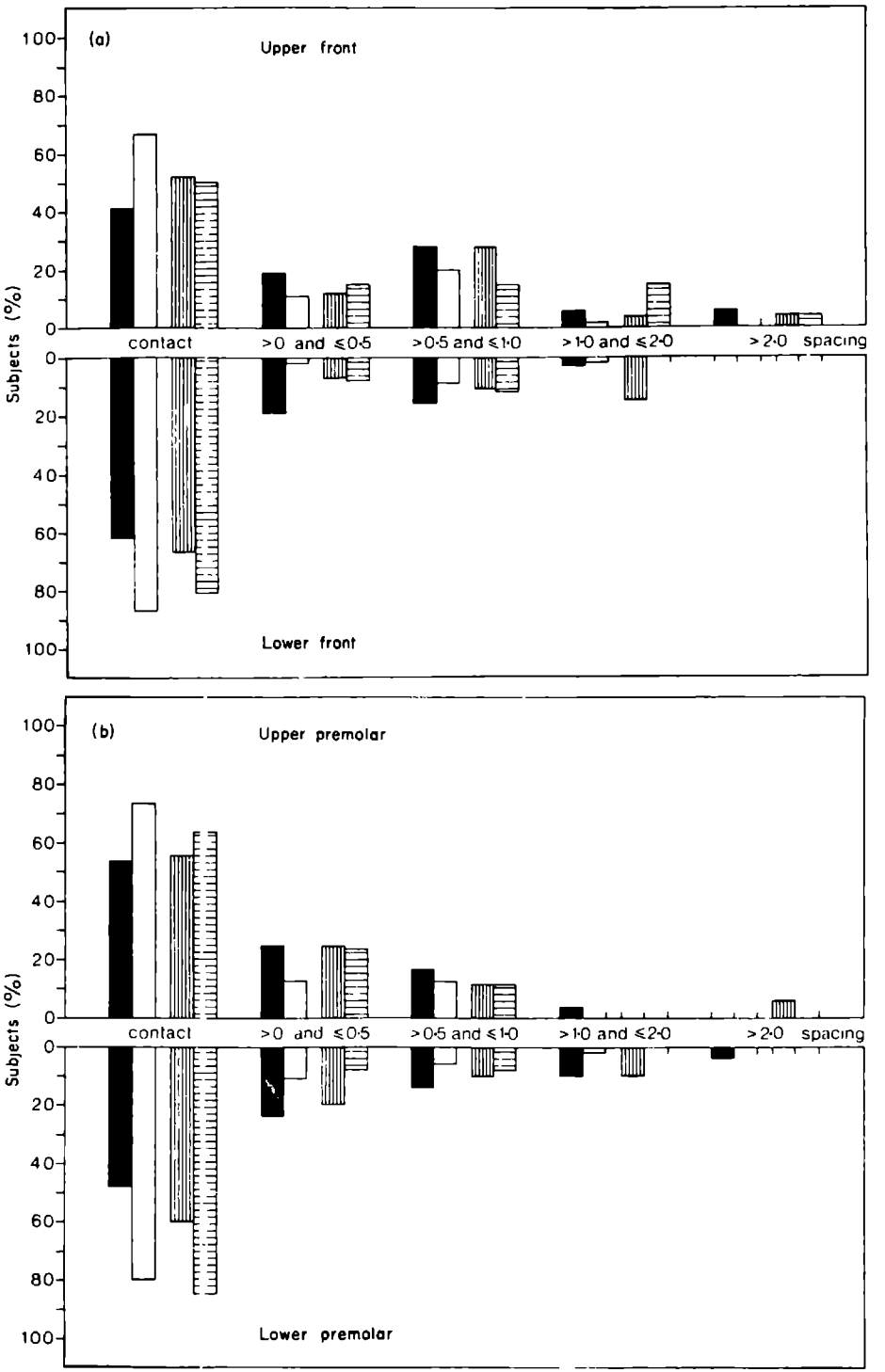

Fig. 4. Distribution of the average interdental contact or spacing for the upper and lower front region (a) and for the upper and lower premolar region (b). (■): SDA<40 years; (□): control<40 years; (▩): SDA≥40 years; (▤): control≥40 years.

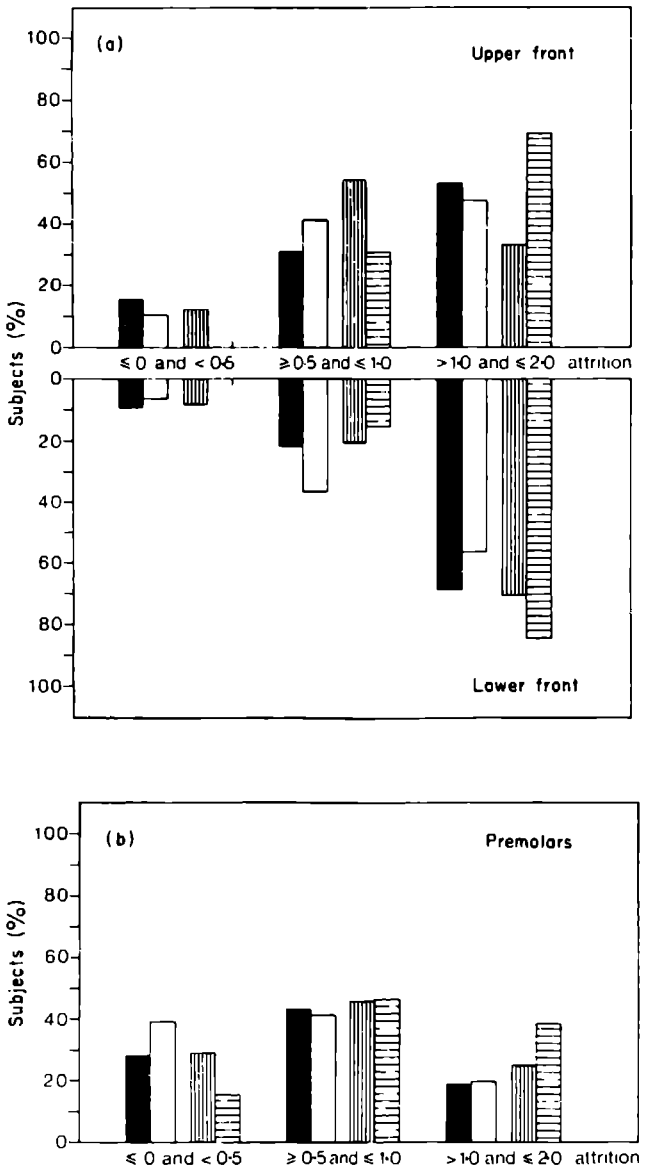

Fig. 5. Distribution of the average degree of attrition in the front region (a) and the premolar regions (b). (■): SDA<40 years; (□): control<40 years; (▦): SDA≥40 years; (▤): control≥40 years.

dentitions (56%). The maxillary incisors had a more corresponding average percentage of occlusal contacts (46%). No significant differences in overbite were found between the four groups. It has been suggested that in normal occlusion the overbite should not exceed one-third of the length of the mandibular incisor. However, the clinical implication of this rule is not substantiated (Ramford & Ash, 1983). In this study the percentage of subjects with an overbite of 6 mm or more is equal amongst the four groups.

Although there was more spacing for the SDA group, particularly for those under 40 years, it must be noted that if spacing exists this spacing is not necessarily large, but within values that also occur in the control groups. The finding that the lower teeth in the SDA group tend to show spacing is interesting. If spacing of the upper front teeth does occur as a result of an increased load, one might expect the lower front teeth to tend to more interdental contact. An explanation might be that the spacing of the upper front teeth is caused by the absence of the anterior component of force when the molars are missing, rather than by an overload of the front teeth.

Spacing by itself does not indicate a pathological condition. Silness & Røynstrand (1984) found that proximal surfaces without interdental contact had a more favourable periodontal condition and fewer restorations than surfaces with contact. Jernberg, Bakdash & Keenan (1983) found less debris at open contacts; however, they found also an increased probing depth (0·27 mm) and attachment loss (0·48 mm).

The results of this study do not confirm increase of wear when the number of teeth decreases. The indices used for the attrition are crude and give no information about the degree of attrition in the dentine. Surprisingly, this study shows less attrition in the SDA group above 40 years than in the control group above 40 years. An explanation might be that the attrition of the SDA group is masked by the relatively high degree of restorative treatment, especially in the older age group. It must be stressed that this study deals with selected subjects with an existing SDA.

Conclusions

The results of this study are in accordance with the results of a previous cross-sectional study of the oral function in SDA (Kayser, 1981). Migration of teeth does occur, but within an acceptable level. Longitudinal data are needed to confirm the findings.

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Chapter 3

Signs and symptoms of mandibular dysfunction in shortened dental arches

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Signs and symptoms of mandibular dysfunction in shortened dental arches*

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Summary

In this study subjects with shortened dental arches (SDA, $n=60$), characterized by the absence of molar support, are compared with subjects with a complete dentition ($n=72$) with respect to signs and symptoms of mandibular dysfunction.

The subjective examination consisted of questions related to pain, noises within the joints and mobility of the lower jaw. The objective examination consisted of the registration of clicking of the temporomandibular joint (TMJ) by bilateral palpation and measuring the maximal mouth opening.

In spite of the finding that significantly more subjects of the SDA group under 40 years of age reported pain in or around the TMJ, it is concluded that in the population studied no convincing evidence was found that a SDA provokes signs and symptoms of mandibular dysfunction.

Introduction

In shortened dental arches (SDA) molar support is absent. This condition was considered to be a prime aetiological factor with respect to mandibular dysfunction (Applegate, 1954; Gerber, 1971). The resulting mandibular overclosure and changes in the position of the condyles and an increased load to the joints are considered to be responsible for the syndrome (mechanical displacement theory) (De Boever, 1979). Studies concerning the relation between the absence of molar support and osteoarthrosis are compiled in Table 1. The conclusion is that morphological changes do occur. However, studies of the relation between the absence of posterior support and signs and symptoms of mandibular dysfunction are not conclusive (Table 2). Based on the available information one may assume that the changes are more adaptive than pathological (Moffett *et al.*, 1964; Magnusson & Carlsson, 1978; Carlsson & Droukas, 1984; Solberg, Hansson & Nordström, 1985). It has been postulated that SDA are able to provide sufficient mandibular stability and oral function when at least 4 occlusal units (OU) are left, preferably in a symmetrical position (Käyser, 1981). To verify this conclusion a study was started with three groups of subjects: a SDA group with 3 to 5 OU (Fig. 1), a SDA group where the SDA is extended with free-end removable partial denture (RPD), and a control group characterized by complete dental arches (Witter, van Elteren & Käyser, 1987).

In this paper the SDA group is compared with the control group at the start of the observation with respect to signs and symptoms of mandibular dysfunction.

*This project was part of the research programme 'Restorations and Restorative Materials'.

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Table 1. Studies of the relation between posterior support and osteoarthrosis of the TMJ

Author (year), country	Subjects	Classification of the dentition	Methods	Results
Steinhardt (1950), F R G	—	Various mutilations	Histological	Change of position of condyles, histopathological changes
Hankey (1954), U K	TMJ patients (n=150)	Uni/bilateral loss of molar support	Roentgenol	Change of position of condyles
Copland (1960), U K	TMJ patients (n=186)	Loss of molar support	Roentgenol	Malocclusion is not a primary aetiological factor
Boering (1966), The Netherlands	TMJ patients (n=159)	Uni/bilateral missing molar support	Roentgenol	Positive correlation only with unilateral function
Oberg, Carlsson & Fajers (1970), Sweden	Autopsy subjects (n=115)	Reduced dentition without molar support	Histological	Positive correlation
Tayler *et al* (1972), U S A	Children and adults (n=112)	Dentitions with loss of vertical dimension	Roentgenol	No correlation with joint morphology
Kopp (1977), Sweden	TMJ patients (n=68)	Uni/bilateral loss of molar support	TMJ-crepitation	Positive correlation
Hansson *et al* (1979), Sweden	Autopsy subjects (n=30)	Uni/bilateral lack of molar support	Histological	Positive correlation
Hansson, Hansson & Petersson (1983), Sweden	TMJ patients (n=259)	Loss of premolar and or molar support	Roentgenol	Positive correlation

Material and methods

Details about the subjects in this study, who were selected from patients of the dental clinic of the University of Nijmegen, are reported in a previous publication (Witter *et al.*, 1987). The SDA group (n=60) had a remaining dental arch of between 3 and 5 OU (Fig. 1). One occlusal unit consists of a pair of antagonistic premolars, one molar unit is considered to be equivalent to 2 OU. Angle class III and extreme class II front relation were excluded. The subjects were divided into an age group under 40 years (n=33, mean age 31·0, standard deviation 4·6 years) and above 40 years (n=27, mean age 51·2, standard deviation 9·2 years). In both age groups about 25% of the subjects had a SDA for 0 till 4 years, 25% for 5 till 9 years, 25% for 10 till 14 years and 25% for 15 years or more.

The subjects of the control groups (n=72) had a complete dental arch and an acceptable front relation. They were also divided in an age group under 40 years (n=46, mean age 29·9, standard deviation 5·2 years) and a group above 40 years (n=26, mean age 47·5 years, standard deviation 4·6 years).

A subjective and objective examination was performed. The subjective examination consisted of questions related to:

(i) pain in or around the TMJ, with differentiation between the sides and the severity; infrequent, light or frequent, heavy pain;

Table 2. Studies of the relation between posterior support and signs and symptoms of mandibular dysfunction

Author (year), country	Subjects	Classification of the dentition	Results
Boering (1966), The Netherlands	TMJ patients (n=159)	Uni- and bilateral molar absence	Positive correlation only with unilateral function
Magnusson & Carlsson (1978), Sweden	TMJ patients (n=80) and controls (n=80)	Eichner's index	No correlation with TMJ dysfunction or headaches
Österberg & Carlsson (1979), Sweden	70-years-old subjects (n=384)	Eichner's index	No or weak correlation with dysfunction
Käyser (1981), The Netherlands	Adults (n=118)	Varying degree of SDA	Positive correlation, only in case of extreme SDA*
Sassen (1982), F.R.G.	Adults (n=181)	Eichner's index	No correlation
De Boever & Adriaens (1983), Belgium	TMJ patients (n=135)	Varying number of occluding posterior teeth	No correlation
Abdel-Hakim (1983), Egypt	Male subjects (n=215)	Premolar/molar support	Suggestion of positive correlation with muscle pain
Pullinger, Xu & Solberg (1984), U.S.A.	TMJ patients (n=128) and age-matched controls (n=71)	Molar, premolar, canine or incisor support	Positive correlation with lack of molar ICP contact
Mejersjö & Carlsson (1984), Sweden	Female TMJ patients (n=154)	Varying degree of posterior support	No correlation
Budtz-Jörgenson *et al.* (1985), Denmark	Elderly subjects (n=146), of which 55 were edentulous)	Eichner's index	Positive correlation in case of extreme SDA

*Extreme SDA=only front teeth remaining.

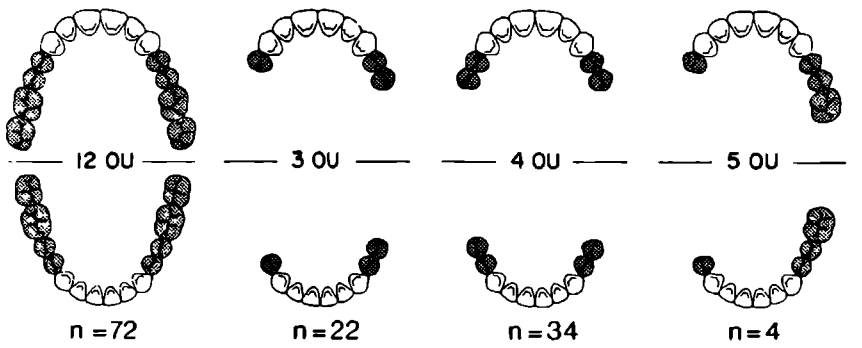

Fig. 1. Representation of the control group (n=72) and the SDA group (n=60). The variation of OU (occlusal units) is shown in shaded teeth.

(ii) noises within the TMJ on measurement (yes/no);
(iii) restricted mobility of the lower jaw (yes/no).

The objective examination consisted of the registration of:

(i) clicking or crepitation of the TMJ, either audible or palpable by bilateral palpation during opening and closing of the mouth, indicating jerky movements of the disc-condyle complex (not, dubious, right sided, left sided or both sides);
(ii) the maximal mouth opening (MMO), measured by adding the maximal interincisal distance between the central incisors and the vertical overbite.

Associated factors to the syndrome that were taken into account (by questioning) were:

(i) general health;
(ii) chewing side preference (bilateral, unilateral, with front teeth, not aware of chewing side);
(iii) clenching or grinding habits (not, sometimes, often).

To verify the clenching or grinding habits objectively the attrition was scored by clinical examination:

grade 0: no wear facets visible;
grade 1: facets in enamel, or in artificial crowns <1 mm;
grade 2: facets in dentine, or in artificial crowns ≥ 1 mm and <2 mm;
grade 3: facets in secondary dentine, or in artificial crowns ≥ 2 mm.

In this study a comparison of the attrition of the lower front teeth is given, as these teeth are less changed by restorations in comparison with the other regions.

For statistical analysis the variables consisting of more than two categories, were reduced to two categories, yes or no (including dubious). The significance of the differences between pairs of yes/no variables was tested by means of Fisher's exact test for 2×2 tables. All *P*-values mentioned concern the two sided version of this test. The statistical analysis of the attrition is reported earlier (Witter *et al.*, 1987).

Results

Figure 2 shows the results of the subjective examination. Comparing the SDA groups with the control groups significant differences are not found with the exception of pain in or around the TMJ. Significantly more subjects under 40 years of the SDA group than the controls under 40 years reported pain ($P=0{\cdot}04$). However, none of the subjects reported frequent or heavy pain.

The results of the objective examination are shown in Fig. 3. Significant differences are not found. None of the subjects had a MMO under 30 mm.

Associated factors to mandibular dysfunction are represented in Fig. 4. Significantly more subjects under 40 years of the SDA group answered that they are chewing with the front teeth or unilaterally ($P=0{\cdot}01$) or have clenching or grinding habits ($P=0{\cdot}0008$), comparing them with the subjects of the control group under 40 years. Comparing the groups above 40 years did not reveal these differences.

For analysing the relation between the subjective associated factors and the signs and symptoms, all subjects under 40 years of both the SDA and the control group have been taken together and also those above 40 years for both groups. It was found

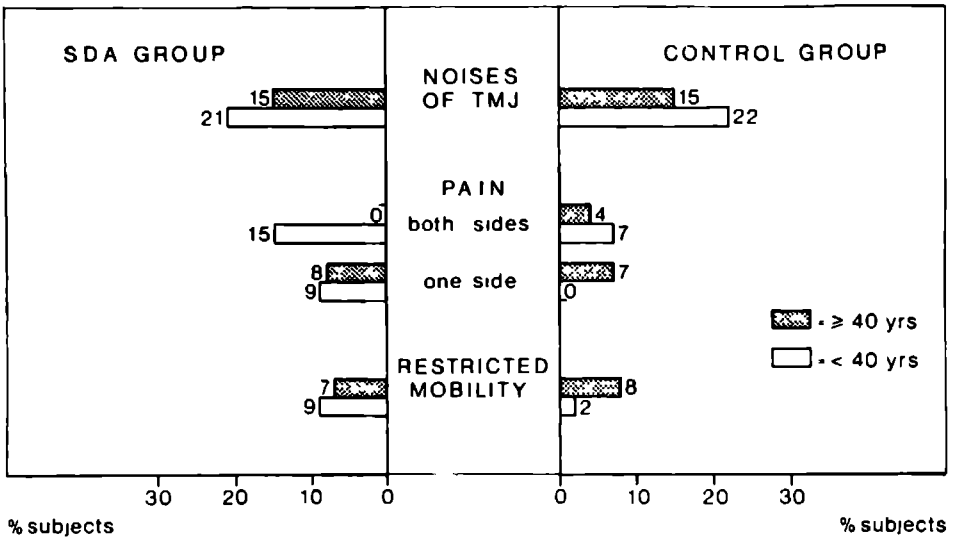

Fig. 2. Percentage of the subjects with subjective signs and symptoms of mandibular dysfunction

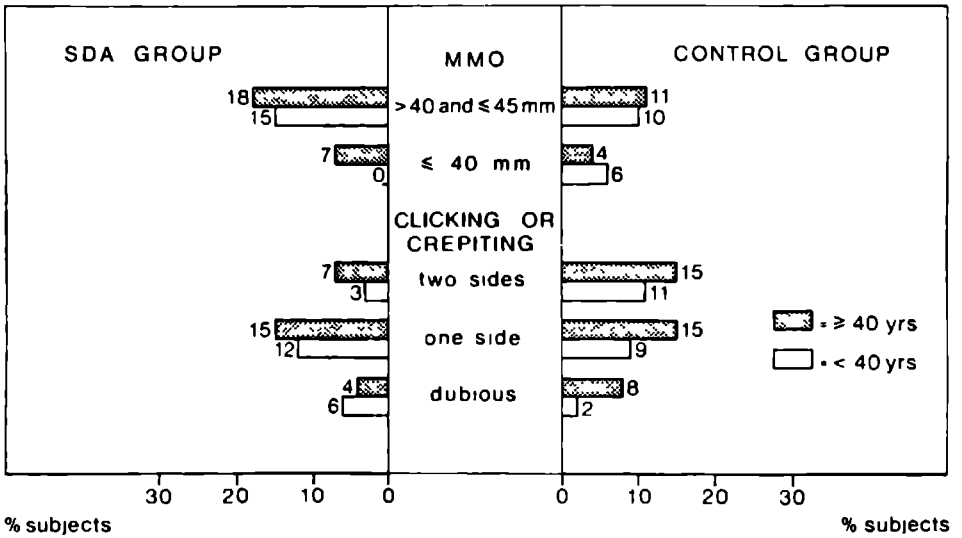

Fig. 3. Percentage of subjects with objective signs and symptoms of mandibular dysfunction

that in subjects under 40 years a clenching or grinding habit is significantly related to pain in or around the TMJ (P=0·009) and nearly significant with restricted mobility of the mandible, reported by the subjects (P=0·06). In subjects above 40 years these relationships were not found. A comparison between subjects who reported unilateral chewing or chewing with the front teeth on the one hand with those who reported bilateral chewing on the other hand did not reveal significant differences with respect to the investigated signs and symptoms. Subjects with an impaired general health did not have significantly more signs and symptoms, in comparison with healthy subjects.

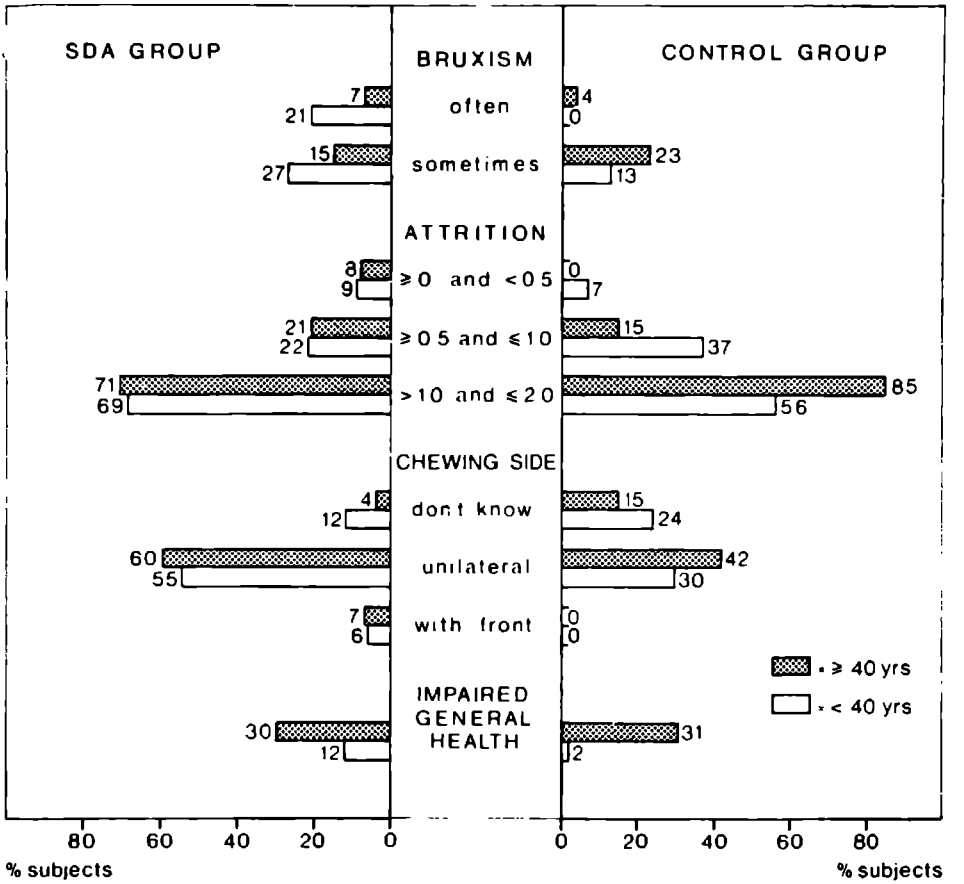

Fig. 4. Distribution of the percentage of subjects with factors that may influence mandibular dysfunction. Attrition is expressed as average scores on the lower front teeth.

Discussion

Comparing the SDA groups and the control group shows that significant differences, with respect to signs and symptoms, are not found with the exception of light or infrequent pain in or around the TMJ, in the subjects under 40 years. It is not surprising that more subjects with SDA reported chewing with the front teeth or unilateral chewing, because the missing posterior teeth and the many asymmetrical dental arches forces them to adapt to this situation (Fig. 1). In accordance with the study of Pond, Narghi & Barnwell (1986) a correlation between dysfunction and chewing side preference was not found. However, Boering (1966), Franks (1967) and Agerberg & Carlsson (1973) found a positive correlation. Clenching or grinding habits are reported by more subjects of the SDA group under 40 years than by those of the control groups. But intensified occlusal attrition as a result of these habits is not found. An explanation might be that subjects with SDA are more aware of their dental situation and habits, as these subjects have had experience with caries and periodontal disease before acquiring a SDA. Another explanation might be that the

front teeth are more sensitive to clenching or grinding forces when molars are absent, so this condition is noticed earlier. In addition the attrition in the SDA group may be masked partly by the more extensive restorative treatment these subjects have undergone in the past.

In contrast with the studies in Table 2, in this study subjects with strictly defined bilateral SDA have been described. Directly comparing these findings with other studies is difficult, especially when the Eichner index or the Helkimo index is not used.

Conclusions

The results of this study suggest that for this population with SDA the absence of molar support does not appear to provoke signs and symptoms of mandibular dysfunction. The presence of bilateral premolar support seems to provide sufficient mandibular stability.

Longitudinal data are needed to confirm these findings.

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Chapter 4

The effect of removable partial dentures on the oral function in shortened dental arches

Journal of Oral Rehabilitation, 1989, Volume 16, pages 27–33

The effect of removable partial dentures on the oral function in shortened dental arches*

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Summary

In this study the effect of free-end removable partial dentures (RPD) on oral function was investigated by comparing subjects with shortened dental arches (SDA, n=55) and a group of subjects with SDA and RPD (n=25). In addition, a group of subjects were selected who had worn an RPD in the past (n=19). All subjects had a remaining natural dentition consisting of an intact front region and three to five occlusal units (OU) in the posterior area.

On the whole, subjects with RPD had less natural OU compared with subjects without RPD. However, this is also true for those who had worn an RPD in the past. The oral functions of subjects with SDA did not differ significantly when compared with subjects with SDA and RPD.

Significantly more subjects who had an RPD in the past reported a limited mobility of the mandible, an impaired chewing capacity and chewing with the front teeth. They also reported more aesthetic complaints due to missing posterior teeth.

It is concluded that within the populations investigated in this study oral function is not evidently improved by the insertion of a free-end RPD.

Introduction

The aim of prosthodontics is the replacement of lost teeth in order to restore lost function. When prescribing a free-end removable partial denture (RPD) to achieve this aim two aspects should be stressed. First, where a free-end RPD replaces lost molars only, it is not quite clear which oral functions have to be improved and to what extent (Pilot, 1978; de Boever, 1985). In addition, free-end RPDs are considered to be dental appliances with potential negative side-effects on the surrounding oral tissues, the so-called biological price (Carlsson, Hedegard & Koivumaa, 1962; Zarb *et al.*, 1978; Monteith, 1984; Berg, 1985). However, under favourable circumstances, which means a regular recall in order to maintain a proper oral and denture hygiene, caries, periodontal disease and other negative effects can be minimized (Bergman, Hugoson & Olsson, 1982; Kerschbaum, 1982; Chandler & Brudvik, 1984; Vermeulen, 1984; Isidor & Budtz-Jørgensen, 1987; Lappalainen, Koskenranta-Wuorinen & Markkanen, 1987). Secondly, it has been shown that there may be sufficient adaptive capacity in the SDA when at least 4 occlusal units (OU) are left, preferably in a symmetrical position, to satisfy functional demands (Käyser, 1981; 1984; de Boever & Adriaens, 1983; Aukes, Kayser & Felling, 1988).

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Consequently, the insertion of free-end RPDs in these situations may not be necessary and may even lead to overtreatment. The aim of this study is to investigate the effect of free-end RPDs on oral function in the case of an SDA consisting of 3 to 5 OU. An investigation was also undertaken to assess the reasons for subjects deciding not to wear an RPD after using them for a certain time in these situations.

Material and methods

Three groups of subjects were selected for this study, one group consisting of subjects with SDA (n=55) and a group of subjects with SDA provided with RPD (n=25). Originally the SDA group consisted of seventy-four subjects. However, nineteen of these had worn a free-end RPD in the past. This group was separated in order to find out why these subjects decided not to continue wearing their RPD.

All subjects were selected from the Dental School clinic at Nijmegen. They had a remaining natural dentition consisting of the front teeth with a normal anterior relation and 3 to 5 occlusal units (OU) posteriorly. One OU is defined as a pair of antagonistic premolars. A pair of antagonistic molars is considered to be equivalent to 2 OU (Witter, van Elteren & Käyser, 1987a).

Table 1 compiles the information related to the three groups with respect to age, the number of OU and the duration of existence of the SDA. The only significant difference is the number of OU: 80% of the SDA group having 4 or 5 OU versus only 36% in the SDA with RPD group and 32% in those who had had an RPD in the past. These differences are highly significant (P=0·0003, χ^2-test for 2×2-table).

Table 2 shows the distribution of the subjects with SDA and RPD according to the number of years they were wearing the RPD. They all had an RPD in the lower jaw with the exception of three subjects, who also had a free-end RPD in the upper jaw. All RPDs in this group were made as metal frames, consisting of a major connector, occlusal rests and clasps with acrylic saddles on the edentulous areas.

Table 1. Distribution of the subjects with SDA (n=55), SDA with RPD (n=25) and SDA with previously worn RPD (n=19), according to age group, number of occlusal units (OU) and the duration of existence of the SDA

	SDA		SDA with RPD		SDA with RPD previously	
	n	(%)	*n*	(%)	*n*	(%)
Age group (years)						
≤34	21	38·2	2	8·0	7	36·8
35–49	22	40·0	15	60·0	7	36·8
≥50	12	21·8	8	32·0	5	26·3
Number of OU						
3	11	20·0	16	64·0	13	68·4
4	39	70·9	3	12·0	5	26·3
5	5	9·1	6	24·0	1	5·3
Duration of SDA (years)						
≤4	12	21·8	3	12·0	3	15·8
5–9	15	27·3	6	24·0	4	21·1
10–14	15	27·3	10	40·0	6	31·6
≥15	13	23·6	6	24·0	6	31·6

Table 2. Distribution of the subjects with SDA and RPD (n=25) according to the duration of wearing the RPD in the lower jaw

		Subjects
Years	n	(%)
≤4	9	36
5–9	8	32
10–14	6	24
≥15	2	8
Total	25	100

Of those who had had an RPD in the past (n=19) ten subjects had worn a free-end RPD in the lower jaw, of which eight were metal frames. Another three subjects had free-end RPDs in both the lower and upper jaw, in one case constructed as metal frames. The remaining six subjects had acrylic RPDs in the upper jaw.

Table 3 summarizes the oral functions investigated in this study and the methods used to measure these functions. Details are reported earlier (Witter *et al.*, 1987a, b).

Results

The objective information gathered from three groups is compiled in Table 4. It shows the results with respect to mandibular stability and TMJ function. Using χ^2-tests for a 2×3-table for each line of Table 4 did not reveal significant differences between the three groups. (With respect to the overbite and the maximal mouth opening the test was applied for the first line of the table versus the other two lines.)

Table 5 gives the subjective information with regard to the chewing function, the TMJ function and bruxism. Differences between the three groups were tested by means of χ^2-tests for a 2×3-table or the exact version of that test in case the numbers

Table 3. An overview of the investigated oral functions and the methods used in this study

Function	Method
Chewing	Questioning
Aesthetics	Questioning
Mandibular stability	
Overbite	Ruler
Spacing anterior teeth	Metal gauges
Occlusal contact	Occlusal strips in IP
Attrition	Measuring occlusal wear
TMJ function	
Pain	Questioning
Noises/clicking	Questioning/palpation
Restricted mobility	Questioning/measuring MMO
(para-) functional habits	
Unilateral chewing	Questioning
Front-chewing	Questioning
Bruxism	Questioning

Table 4. The results with respect to mandibular stability (items 1–4) and TMJ function (items five and six). Percentages refer to total number of subjects (fifty-five for SDA, twenty-five for SDA and RPD, nineteen for SDA with RPD previously)

	SDA		SDA and RPD		SDA with RPD previously	
	n	(%)	*n*	(%)	*n*	(%)
Occlusal contact						
Tooth 11	34	61·8	15	60·0	14	73·7
Tooth 12	27	49·1	13	52·0	14	73·7
Tooth 13	48	87·2	19	76·0	17	89·5
Interdental contact						
Tooth 11–21	40	72·7	16	64·0	14	73·7
Tooth 11–12	34	61·8	17	68·0	12	63·2
Tooth 12–13	34	61·8	15	60·0	14	73·7
Overbite						
≥−1 and ≤2 mm	10	18·2	11	44·0	6	31·6
3 or 4 mm	33	60·0	10	40·0	10	52·6
5 or 6 mm	12	21·8	4	16·0	3	15·8
Wear in dentine						
Tooth 41	34	64·2*	17	89·5**	12	70·6***
Tooth 42	30	56·6	12	63·2	10	58·8
Tooth 43	31	58·5	13	68·4	7	41·2
Clicking/noises TMJ	17	30·9	10	40·0	7	36·8
Max. mouth opening						
30–40 mm	2	3·6	4	16·0	3	15·8
41–50 mm	30	54·5	12	48·0	8	42·1
≥51 mm	23	41·8	9	36·0	8	42·1

Of 2*, respectively 6** and 2*** subjects the data with respect to the attrition was not available.

were too small. Significant results, due to a high incidence in the SDA group with RPDs in the past were found for an impaired chewing capacity (P=0·0002, exact version), chewing with the front region (P=0·0002, exact version) and for restricted mobility (P=0·01, exact version). Also more subjects of this group had complaints about their aesthetics (P=0·03, exact version), because of missing posterior teeth.

Discussion

In the literature loss of molars is associated with impaired oral function. Many prosthetic textbooks claimed that without molars the chewing function, occlusal stability and TMJ function are negatively affected. This presupposition has led automatically to the insertion of free-end RPD in these situations. In this study the most important oral functions were compared using objective and subjective measuring methods.

When comparing subjects with SDA and subjects with SDA and RPD the results do not reveal great differences. As a whole subjects with RPD had less occlusal units (Table 1). The elongation of their SDA with RPD did not give them subjectively a better chewing function than those without RPD (Table 5). Although several studies showed that the chewing capacity is closely related with the number of occluding pairs of teeth (Helkimo, Carlsson & Helkimo, 1978; Käyser, 1981; Luke & Lucas,

Table 5. Subjective information with respect to chewing function, aesthetics and TMJ function. Percentages refer to total number of subjects (fifty-five for SDA, twenty-five for SDA and RPD, nineteen for SDA with RPD previously)

	SDA		SDA and RPD		SDA with RPD previously	
	n	(%)	*n*	(%)	*n*	(%)
Chewing function						
Impaired capacity	1	1·8	1	4·0	6	31·6
Unilateral	31	56·4	13	52·0	9	47·4
Front region	1	1·8	0	0	5	26·3
Aesthetic complaints	4	7·3	1	4·0	5	26·3
TMJ function						
Pain	10	18·2	3	12·0	4	21·1
Noises	15	27·3	5	20·0	5	26·3
Restricted mobility	2	3·6	0	0	4	21·1
Bruxism	17	30·9	12	48·0	6	31·6

1985) large interindividual differences within groups with similar dental conditions were found (Gunne, 1985a; Käyser, 1981; Imperiali, Grunder & Lang, 1984).

It may be assumed that there is a compensating mechanism by chewing on the longest side of the dental arch and chewing longer before swallowing. Compensation by an intensified use of the front teeth was not necessary for the SDA group of this study with 3 to 5 OU, as shown in Table 5. Gunne (1985b) reported the improvement of the chewing efficiency by free-end RPD, but these subjects had full dentures in the upper jaw and an extreme SDA in the lower jaw. Jemt, Hedegard & Wickberg (1983) concluded that rehabilitation with bilateral distal-extension RPD did not change general masticatory function to any great extent. Battistuzzi, Käyser & Kanters (1987) reported that only in extreme SDA the subjective chewing function is improved by wearing a free-end RPD.

Subjects with RPDs in the past have about the same distribution of the number of OUs as those still wearing their RPD (Table 1). The dental condition does not seem to play an important role in discontinuing the use of an RPD. Obviously there must be a strong patient-related factor associated with wearing the RPD or not.

In the past subjects with RPDs have reported a significantly higher percentage of complaints about their dental aesthetics because of missing posterior teeth as well as about their chewing capacity. They might have had adaptation problems in their chewing function. However, these problems obviously were not solved adequately by the RPD as they stopped wearing them. Of course, the complaints still do persist after discarding the RPD, but seem to be acceptable for the subjects involved.

In the past TMJ dysfunction is often related with loss of molar support. Recent studies showed that clinical distress should be distinguished from morphological and adaptive changes (Carlsson & Droukas, 1984; Mejersjö & Carlsson, 1984). As reported earlier (Witter *et al.*, 1987, 1988) the support of SDA with between 3 and 5 OU to the remaining dentition as well as to the TMJ is sufficient and noted changes are within acceptable levels.

These results support the approach of De Boever (1985) who recommended the replacement of bilaterally lost molars only in the case of continued distress of the TMJ.

Conclusions

The results of this study do not indicate that oral functions are improved by the insertion of an RPD in the case of an SDA with 3 to 5 OU.

It appears that the factor 'dentist' plays a larger role in the prescription of a free-end RPD than the oral condition of the patient Patient-related factors seem to be the major reason to stop wearing a free-end RPD

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Chapter 5

Oral comfort in shortened dental arches

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Oral comfort in shortened dental arches*

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Summary

In this study, the oral comfort was compared between subjects with shortened dental arches (SDA, $n = 74$), subjects with SDA and free-end removable partial dentures (SDA + RPD, $n = 25$) and subjects with complete dental arches (CDA, $n = 72$).

Oral comfort was measured by (i) absence of pain or distress; (ii) chewing ability; (iii) appreciation of the appearance of the dentition. Additionally, the history of free-end RPD over a period of nearly 7 years was taken into consideration.

On the whole, the results did not reveal any significant differences between the three groups with respect to pain or distress. Only 8% of the subjects with SDA reported impairment of chewing ability, and 11% had aesthetic complaints, due to missing posterior teeth in the upper jaw. Of the subjects with SDA + RPD, 20% had complaints about the RPD. In addition, the repeated necessity for repair or replacement of free-end RPD and the fact that some subjects (20%) stopped wearing the RPD during the observation period, confirm the poor performance of this dental provision. It is concluded that the oral comfort of subjects with SDA in this study is compromised to a small extent but remains on an acceptable level. Free-end RPDs do not appear to help oral comfort in these cases.

Introduction

On the basis of clinical observations as well as research findings, it is postulated that shortened dental arches (SDA) do provide sufficient oral function when at least four occlusal units (OU) are present, preferably in a symmetrical position (Käyser, 1981; Budtz-Jørgensen & Isidor, 1987). However, in these studies oral comfort was not investigated extensively.

Oral comfort has a part in the quality of life of a person, and it is becoming more important nowadays in evaluating the oral function. It is related to dental health and dental state on the one hand, and has social and psychological effects on the other (Ettinger, 1987).

The aim of this study was to compare the oral comfort of a population with SDA ($n = 74$), a population with SDA and free-end RPD ($n = 25$) and of a population with complete dental arches (CDA, $n = 72$), the last group being the control group.

In this study oral comfort was defined using the following parameters.

(i) The absence of pain or distress of the stomatognathic system.

*This project was part of the research programme 'Restorations and Restorative Materials'.

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(ii) A satisfactory masticatory ability, such that the subjects report normal eating habits and require no change in food selection or food preparation due to masticatory impairment.

(iii) Acceptable aesthetics, such that the subjects judge the absence of posterior teeth to be barely visible, if at all, and consequently that it does not alter their appearance.

Finally it was felt that incidents with free-end RPD (repair, replacement) may affect oral comfort, because of the required adaptation to an altered situation. For this reason the history of free-end RPD was investigated over a period of 6·9 years.

Material and methods

Details of the subjects of this study have been reported elsewhere (Witter, Van Elteren & Käyser, 1988; Witter *et al.*, 1989). In summary: (i) the subjects of the SDA group (n = 74) and the SDA + RPD group (n = 25) had a reduced dental arch consisting of the front teeth, and between three and five occlusal units (OU). Of these subjects about 25% had a SDA for 0–4 years, 25% for 5–9 years, 25% for 10–14 years and 25% for 15 years or more; (ii) subjects with free-end RPD were provided with a metal frame RPD. They all wore a RPD in the lower jaw, with the exception of three subjects who also had a free-end RPD in the upper jaw. About 30% wore the RPD for 0–4 years, 30% for 5–9 years, 30% for 10–14 years and two subjects for 15 years or more; (iii) all subjects were selected from the Dental School Clinic in Nijmegen, The Netherlands.

When comparing the three groups (Table 1), no significant relationship was found between sex and group (Chi-square test 2 × 3 table, P = 0·28). For both sexes, a significant relationship was found between age and group according to the Kruskal–Wallis test: for men P = 0·049 (with a higher mean age for the SDA + RPD group), for women P = 0·018 (with a higher mean age for the SDA and the SDA + RPD group).

Details of the assessment of the objective signs and symptoms of mandibular dysfunction (MD) are given elsewhere (Witter *et al.*, 1988).

The information required regarding the function of the stomatognatic system, aimed at aspects of masticatory ability and aesthetics, was gathered by questionnaire. The questions related to missing posterior teeth and complaints about the RPD.

The incidents of the RPD were investigated by examining the patients' records over a period of 6·9 years (1 January 1981 to 1 October 1987). During this period complete data from twenty-three subjects, with free-end RPD at the start of the observation period, were available.

Results

Table 2 presents the perceived oral comfort of the subjects with SDA (n = 74), relating to chewing ability and aesthetics. For subjects with SDA + RPD (n = 25) the problems with the RPD are also given.

Whereas five subjects of the twenty-five (20%) with SDA + RPD had complaints about the RPD, 8% of the SDA group reported impairment of the chewing ability and 11% had aesthetic complaints due to missing posterior teeth in the upper jaw. In the CDA group no complaints were reported about the chewing ability.

Subjective signs and symptoms of mandibular dysfunction (MD) are given in Table 3. None of the subjects reported heavy or frequent pain; they all considered the pain

Table 1. Distribution of the subjects according to sex, age and group

Group	Sex		Age			
			♀		♂	
	♀	♂	Mean	S D.	Mean	S D
CDA	37	35	36·4	9·9	36 1	10·0
SDA	45	29	42 9	12·7	36·9	9·2
SDA + RPD	17	8	43·2	7·5	46 0	10·5

Table 2. Distribution of the SDA subjects and SDA + RPD subjects according to the chewing ability, the aesthetic evaluation and complaints about the RPD

	SDA (n = 74)		SDA + RPD (n = 25)	
	n	%	n	%
Chewing ability				
Chewing takes too much time	4	5 4	0	0
Must swallow food coarsely	2	2 7	0	0
Cannot chew all food	0	0	0	0
Have to use special (prepared) food	0	0	0	0
Other complaints	0	0	1	4·0
Aesthetic complaint (upper jaw)				
Due to missing molars(s)	3	5·4*	–	–
Due to missing second premolar	3	5·4*	–	–
RPD				
Insufficient retention	–	–	3	12 0
Aesthetic complaints	–	–	0	0
RPD causes pain	–	–	0	0
More than one complaint	–	–	2	8·0

*Percentages based on a total of 56, as 18 of the 74 subjects had a complete dental arch in the *upper* jaw.

– if present – to be mild and infrequent in character. Using Chi-square tests for 2 × 3 tables, significant differences between the three groups were not found (for applying the test the percentages of left- and right-sided and bilaterally pain were taken together, versus no pain).

Table 4 shows the data for factors related to MD. Subjects with SDA + RPD reported significantly more bruxism than subjects with CDA ($P < 0{\cdot}028$, simultaneous test for comparing the groups two by two based on the Chi-square test for 2 × 2 tables and the Bonferroni inequality). Subjects with SDA reported significantly more unilateral chewing or chewing with the front teeth than those with CDA ($P < 0{\cdot}005$, same simultaneous test).

Problematic incidents with free-end RPD in the lower jaw of 23 subjects, as recorded in the patient files, are shown in Table 5. As appears from the files, four of the 23 subjects had none of these incidents. Six subjects needed only one rebasing

Table 3. Distribution of the subjects of the three groups according to subjective signs and symptoms of mandibular dysfunction

	CDA (n = 72)		SDA (n = 74)		SDA + RPD (n = 25)	
	n	%	n	%	n	%
Pain in/around TMJ						
Left side	0	0	3	4 1	1	4 0
Right side	2	2 8	3	4 1	0	0
Bilateral	4	5 6	8	10 8	2	8 0
Noises of TMJ	15	20 8	20	27 0	5	20 0
Restricted mobility	3	4 2	6	8 1	0	0

Table 4. Distribution of the subjects of the three groups according to related factors to MD, bruxism, chewing side preference and general health

	CDA (n = 72)		SDA (n = 74)		SDA + RPD (n = 25)	
	n	%	n	%	n	%
Bruxism						
Sometimes	12	17 1*	14	19 2†	8	32 0
Often	1	1 4*	9	12 3†	4	16 0
Chewing side preference						
Left	13	18 1	18	24 3	6	24 0
Right	12	16 7	22	29 7	7	28 0
Front teeth	0	0	6	8 1	0	0
Not aware of side	15	20 8	10	13 5	1	4
General health						
Impaired	5	6 9	12	16 0	3	12 0
Gastric disorders	4	5 6	3	4 0	0	0

*Percentages based on a total of 70 as two subjects did not know
†Percentages based on a total of 73 as one subject did not know

Table 5. Incidents of free-end RPD in the lower jaw, noted in the records of twenty-three subjects during 6 9 years

Incident	No of RPD
Clasp broken off, no repair	5
Two clasps broken off, no repair	1
Repair of RPD	3
Rebasing once of RPD	7
Rebasing twice of RPD	1
Rebasing four times of RPD	1
New RPD inserted	4
New RPD inserted twice	1
RPD no longer used (not replaced)	5

during the period of this study, indiating that in ten cases the RPD functioned well.

Discussion

Only a few subjects with SDA reported complaints about chewing ability, indicating an insufficient compensation or adaptation in these cases.

The finding that without molars the chewing ability is impaired slightly is reported in other studies (Table 6). The subjective chewing ability seems to be good as long as at least 20 'well-distributed' teeth are present. This is in contrast with the results of studies where the objective chewing performance was measured with a chewing test, using hard food such as peanuts, carrots, almonds or Optosil® (Yurkstas, 1954; Kayser, 1981; Chauncey *et al.*, 1984; Luke & Lucas, 1985). These studies report a decrease in the objective chewing performance in relation to a reduction of the dentition or the chewing platform area. However, studies concerning the relationship between the state of the dentition and the dietary intake or food selection are not conclusive. A conclusion might be that only severe dental impairment affects food selection (Chauncey *et al.*, 1984). Moreover, even if the masticatory performance is poor, a connection with general health, gastric distress or dietary inadequacy cannot be substantiated (Farrell, 1956; Mumma & Quinton, 1970; Osterberg & Steen, 1982; Sircus & Presscott, 1985).

Though laboratory research designs showed an increase in chewing performance after the insertion of free-end RPD (Table 7), this does not mean that the chewing ability in terms of comfort is also increased. Only in case of extreme SDA do free-end RPD have a positive effect on the chewing ability (Table 7).

In this study 11% of the subjects with SDA had aesthetic complaints, due to a missing second premolar or first molar in the upper jaw. This supports the results of

Table 6. Studies of the relation between the subjective chewing ability (chewing comfort) and the state of the dentition

Author	No of subjects	Result
Haraldson & Carlsson (1979)	24	Median of 9 pairs of occluding teeth seem to provide sufficient efficiency
Agerberg & Carlsson (1981)	1106	20 well-distributed teeth are needed for satisfactory chewing ability
Chauncey *et al* (1984)	420	Severe dentate impairment (at least one full denture) may impose certain dietary restrictions
Kayser (1981)	118	Discomfort begins with less than 10 occluding pairs of teeth
Imperiali, Grunder & Lang (1984)	300	Not related with number of teeth
Battistuzzi, Kayser & Kanters (1987)	750	Weak correlation with the number of missing teeth
Aukes, Käyser & Felling (1988)	97	Minor differences between subjects with SDA and CDA

Table 7. Studies of the effect of free-end RPD on masticatory function

Author	No of subjects	Method	Result
Abel & Manly (1953)	103	Pulverization test*	Improvement in chewing efficiency
Plotnick, Beresin & Simkins (1975)	102	Pulverization test*†	Improvement in chewing efficiency
Jemt, Hedegard & Wickberg (1983)	10**	Chewing pattern‡	RPD did not change masticatory function to a great extent
Gunne (1985)	19	Pulverization test§ questionnaire	Improvement of efficiency and ability, no changes of diet
Battistuzzi *et al* (1987)	322 free-end spaces	Questionnaire (chewing comfort)	Only improvement in case of extreme SDA)

Test food *peanuts, †carrots, ‡hard bread, §formalin-hardened gelatin, almonds
**Extreme SDA, only front teeth remain

Tjan, Miller & The (1984), that 'an average smile displays the six upper anterior teeth and premolars'.

With respect to signs and symptoms of MD, it has been reported elsewhere (Witter *et al.*, 1988) that the absence of posterior support is not a prime aetiological factor in provoking MD. In addition to the results of the subjective examination of this study, it can be noted that with respect to the objective temporomandibutar joint (TMJ) examination no significant differences for noises were found between the three groups. However, there is an indication that the SDA + RPD group had a smaller average mouth opening (mean 47·6 mm, S.D. 7·4 mm) than the control group (mean 51·0 mm, S.D. 6·4 mm) (Sheffe's simultaneous comparison test, $P = 0{\cdot}085$). The mean maximal mouth opening of the SDA group was 49·4 mm, S.D. 6·5 mm.

Free-end RPD in SDA consisting of 3–5 OU did not provide improvement of oral function in terms of oral comfort (Tables 2, 3 & 4) In fact in these circumstances further treatment was necessary (Table 5). In general these findings are in accordance with those of Watson *et al.*, (1986), and Budtz-Jørgensen & Isidor, (1987).

Conclusions

(i) SDA (consisting of 3–5 OU) in the subjects of this study appear to provide sufficient oral comfort.

(ii) Free-end RPD (in the lower jaw) did not contribute to oral comfort in these cases.

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Chapter 6

Shortened dental arches and masticatory ability

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Short Review

Shortened dental arches and masticatory ability*

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ABSTRACT

In a previous study concerning oral function with shortened dental arches, it was found that approximately 10 per cent of the patients investigated complained of impaired masticatory ability despite a substantial reduction in arch length and, as a consequence food platform area. This finding differs from those of studies relating masticatory performance to food platform area. From a review of pertinent literature, it is concluded that impairment of masticatory ability is manifest when < 10 occluding pairs of teeth are present. Shortened dental arches are not associated with shifts in food selection adversely affecting general health.

KEY WORDS: Mastication. Partially edentate. Diet.

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INTRODUCTION

In patients with shortened dental arches (SDA), the food platform area (FPA) is considerably reduced. In a previous study (Witter *et al.*, 1990), 74 patients with SDA were investigated regarding their oral functions. Although the molar units, which are specially adapted for chewing, were absent, it was found that only 10 per cent of the patients reported impairment of masticatory ability, four patients (5 per cent) reporting chewing took too long and in some cases (3 per cent) had to swallow food incompletely chewed. None of the patients were found to have atypical diets or to eat specially prepared food, indicating that impairment of masticatory ability is not associated with a shift in food selection.

The aim of this paper is:

1. To compare the above findings with those of other studies, especially as it is widely accepted that a substantial reduction in the food platform area leads to a substantial reduction in masticatory performance.

2. To review reported changes, if any, in the dietary intake and general health of patients with impairment of masticatory ability.

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DEFINITIONS

Masticatory performance is defined as the masticatory performance (or capacity or efficiency) of the dentition as a result of an objective and repeatable laboratory test (Feldman *et al.*, 1984).

Masticatory ability is defined as the subjective self-assessment of subjects concerning their chewing capacity and chewing comfort, obtained by questionnaire or interview (Agerberg, 1988).

MASTICATION, DIET AND THE DENTITION

Masticatory performance deals with objective measurements in laboratory investigations, such as pulverization tests in 20 or 40 stroke 'masticatory performance tests' or a 'swallowing threshold performance test'. The results of such tests are usually expressed as 'masticatory effectivity', 'masticatory coefficient' or 'masticatory efficiency'. Most tests employ hard foods such as peanuts, carrots or almonds or hard food substitutes. In general, researchers in this field have found a close relationship between masticatory performance and the FPA or the number of antagonistic pairs of teeth (*Table I*). The masticatory performance of full denture wearers would appear to be

Table I Studies of the relation between the state of the dentition and the (objective) masticatory performance

Author, year, country	*Subjects (no.)*	*Results, conclusions*
Dahlberg, 1946, Sweden	33	Number of strokes before swallowing with good or poor dentition is about the same*
Manly, 1951, USA	103	Related to food platform area†‡
Abel and Manly, 1953, USA	240	Great improvement in chewing efficiency after insertion of partial dentures‡
Yurkstas, 1954, USA	741	Related to food platform area‡
Kapur and Soman, 1964, USA	140	Chewing efficiency of denture wearers is less than one-sixth that of subjects with a natural dentition†‡
Helkimo *et al*, 1978, Sweden	139	Related to number of occluding pairs of teeth§
Käyser 1981, The Netherlands	118	Correlated with number of occluding units†
Chauncey *et al*, 1981 USA	556	Related to dentition status†
Luke and Lucas, 1985, UK	32	Correlation with occlusal area of posterior teeth†
Omar *et al*, 1987, UK	50	Correlated with Occlusal Index and teeth in occlusal contact¶

Test food *standard meal †carrots ‡peanuts, §almonds, ¶Optosil (Bayer Dental Leverkusen, FRG)

Table II Studies of the relation between the state of the dentition and the (subjective) chewing ability

Author, year, country	*Subjects (no.)*	*Results, conclusions*
Bergman and Carlsson, 1972 Sweden	54	Most of complete denture wearers satisfied with chewing ability
Haraldson and Carlsson, 1979 Sweden	24	Median of nine pairs of occluding teeth seem to provide sufficient efficiency
Agerberg and Carlsson, 1981 Sweden	1106	Twenty well-distributed teeth needed for satisfactory chewing ability
Chauncey *et al*, 1981, USA	566	Not related to partially compromised dentition
Käyser, 1981, The Netherlands	118	Discomfort begins with less than four occluding units (20 occluding teeth)
Imperiali *et al*, 1984, Switzerland	300	Not related to number of teeth
Budtz-Jörgensen *et al*, 1985, Denmark	146	Many elderly with full dentures or missing supporting zones have impaired masticatory function
Battistuzzi *et al*, 1987 The Netherlands	750	Weak correlation with the number of missing teeth
Lappalainen and Nyyssönen, 1987, Finland	3870	Partial and full dentures, especially in the elderly result in a considerable amount of impaired chewing ability
Aukes *et al*, 1988, The Netherlands	97	Small differences between subjects with complete dental arches and SDA
Witter *et al*, 1989, The Netherlands	74	Ten per cent of subjects with SDA raised complaints about masticatory ability

about one-sixth of that of subjects with a complete natural dentition (Yurkstas, 1954, Kapur and Soman, 1964)

Masticatory ability and the dentition

Studies on the relationship between masticatory ability and the dentition are usually performed by interview or questionnaire to investigate complaints and the perceived ease of chewing different kinds of food. From these studies it would appear that impairment of chewing ability is associated with less than 20 'well-distributed' teeth or 10 occluding pairs of teeth (*Table II*)

Problems concerning masticatory ability tend to be associated with patients, particularly the elderly, with very few teeth or with full dentures (Smith and Sheiham, 1979, Wayler and Chauncey, 1983, Budtz-Jorgensen *et al*, 1985,

Table III. Studies of the relation between the state of the dentition and the dietary intake or food selection (by questionnaire or interview)

Author, year, country	*Subjects (no.)*	*Results, conclusions*
Manly and Shiere, 1950, USA	50	Not related to masticatory performance and food platform area, but with maximum biting force
Yurkstas and Emerson, 1964, USA	56	Indication that denture wearers tend to avoid foods which are difficult to chew
Neill and Phillips, 1970, UK	53	With poor masticatory performance intake still within recommended levels
Heath, 1972, UK	75	Selection of food partially related with dental condition
Ettinger, 1973, Australia	700	Most subjects seem to manage food intake, even without teeth
Hartsook, 1974, USA	46	Dietary adequacy not impaired by full dentures
Chauncey, *et al.*, 1981 ,USA	566	With greater masticatory impairment shifts in food selection might affect nutrition
Österberg and Steen, 1982, Sweden	368	Insufficient intake of some nutrients related to degree of dental invalidity
Wayler and Chauncey, 1983, USA	814	Shifts of food selection appear to be influenced by the degree of dental impairment
Chauncey *et al.*, 1984, USA	420	Severely dentate-impaired persons may have certain dietary restrictions
Gunne and Wall, 1985, Sweden	43	No change in dietary intake after insertion of new full dentures
Gunne, 1985, Sweden	19	No change in dietary intake after insertion of free-end removable partial dentures
Aukes *et al.*, 1988, The Netherlands	97	Minor differences in food choice between subjects with complete dental arches and SDA
Ekelund, 1989, Finland	480	Forty per cent of institutionalized elderly were unable to eat some foods because of their teeth

Shatenstein, 1986; Lappalainen and Nyyssönen, 1987, Agerberg, 1988; Ekelund, 1989).

Dietary intake and the dentition

Studies concerning dietary intake and the dentition tend to be based on dietary interviews, questionnaires and examinations of the composition of meals From the findings of such studies (*Table III*), it may be concluded that only in cases of severe masticatory impairment there is a shift in food selection towards soft, easy to chew foods. Such a shift may be most likely to occur when only a few teeth remain, in subjects who have not adapted to complete or removable partial dentures (Agerberg, 1988; Ekelund, 1989). In present-day society, economical and sociopsychological factors are believed to be more important regarding food selection than physiological factors, such as the state of the dentition (Sandstead, 1987).

Masticatory function and general health

The relation between masticatory function and general health is usually investigated by studying haematological data of nutrients and dietary elements such as vitamins and minerals. Gastrointestinal investigations also have an important role in such studies. Although Hermann (1967) suggests a correlation between tooth loss and gastrointestinal disorders, other studies (*Table IV*) give little support to this statement. From a review of the relevant literature (*Table IV*) it is concluded that impaired masticatory function, as a result of tooth loss, is not associated with a deterioration in general health.

DISCUSSION

In 1965 Wheeler stated that, 'The primary function of the dental apparatus is, of course, the mastication of food' and in 1974 Kawamura wrote, 'Among the functions of the mouth, mastication of food is one of the most important human functions' While the mastication of food is still considered to be an important function of the dentition, it is suggested that mastication is now considered to be only one of the functions of the dentition Other functions which have assumed greater importance since the time of Wheeler (1965) and Kawamura (1974) include communication (appearance and speech) and psychological functions (satisfaction, self-esteem). With such changes the dentition is increasingly considered as an integral part of the stomatognathic system. It is of particular note that some of the differences between the results and conclusions of studies concerning masticatory performance and masticatory ability may be attributed to differences in

Table IV. Studies of the relation between masticatory performance and general health

Author, year, country	*Population*	*Method*	*Results, conclusions*
Farrell, 1956, UK	10 healthy subjects	Size of residues in faeces	The amount of required chewing is surprisingly small for digestion of food
Mumma and Quinton, 1970, USA	129 hospital patients	Gastrointestinal complaints	Masticatory efficiency does not affect gastric distress
Neill, 1969, UK	576 subjects	Questionnaire	Elderly male subjects with full dentures consumed more calories than those with natural teeth
Bates *et al*, 1971, UK	704 elderly	Haematological data	Dentition is not essential for satisfactory nutritional state
Berry, 1972, UK	Over 700 elderly	Energy intake	Mechanical inefficiency is not a critical issue
Elwood and Bates, 1972, UK	About 700 elderly	Weight, haematological data	Masticatory performance not related with impairment of nutritional status
Hartsook, 1974, USA	46, partially or fully edentulous	Dietary elements	Dietary adequacy does not differ markedly from general population
Baxter, 1984, USA	60 geriatric and 20 non-geriatric patients	Intake of nutrients	Dietary inbalances not unique for any particular oral condition
Österberg and Steen, 1982, Sweden	368 70-year-old subjects	Dietary elements	Insufficient intake of certain nutrients related to dental invalidity
Sircus and Presscott, 1985, UK	400 patients, undergoing endoscopy	Endoscopic findings	No significant relation with dyspepsia
Halling *et al*, 1988, Sweden	437 women	Dietary history	No significant differences between those with more or less than 15 teeth

design and population (*Fig 1*) However the schematical representation in *Fig 1* gives no indication of the large variation between individuals, the greatest discrepancy between masticatory performance and ability being related to SDA. However, in the case of extreme SDA when only the anterior teeth remain ('Extreme SDA'), both masticatory performance and masticatory ability are generally unacceptable

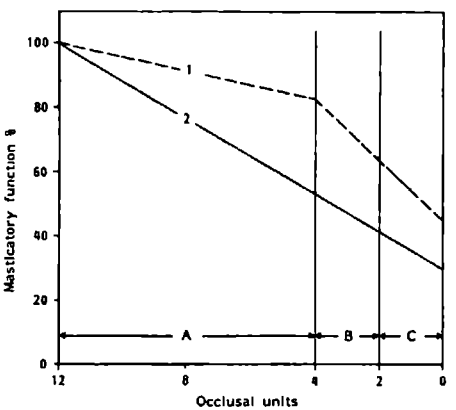

Fig 1 Schematic representation of the relation between masticatory function and dental arch length (expressed in occlusal units) 1, Masticatory ability (perceived ease of chewing). 2, masticatory performance A, Area of sufficient masticatory function, B, turning range, C, area of insufficient masticatory function

CONCLUSIONS

1 Masticatory performance, as measured in laboratory tests, is decreased by a reduction in the dental arches and the masticatory platform area The relationships between masticatory performance and the mastication platform area are considered to be linear

2 Masticatory ability is generally sufficient as long as 20 or more 'well-distributed' teeth remain, such as in cases of SDA.

3 Studies on the relation between the state of dentitions and dietary intake indicate that only severe dental impairment affects food selection It is not considered that SDA leads to shifts in food selection

4 There would not appear to be a relationship between poor masticatory performance and gastric disorders, dietary inadequacy and deterioration in general health

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Chapter 7

Shortened dental arches and periodontal support

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Shortened dental arches and periodontal support*

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Summary

The periodontal support of subjects with shortened dental arches (SDA, $n=74$), and of subjects with SDA and free-end removable partial dentures in the lower jaw (SDA and RPD, $n=25$) was compared with that of subjects with complete dental arches (CDA, $n=72$). The periodontal support was determined by tooth mobility and alveolar bone height, measured on a radiograph, of the distal alveolar bone of the premolars. Significant differences in tooth mobility were found between the three groups of subjects. The relative bone height showed a trend towards lower values for the SDA group and the SDA and RPD group. For some teeth these differences were significant. Premolars that are the most posteriorly located occluding teeth in the dental arch tend to have a lower relative alveolar bone height than premolars in an intermediate location. This effect is more marked in the upper jaw than in the lower jaw. Premolars in the lower jaw, that serve as abutment teeth for free-end RPDs, tend to show lower values for the relative bone height.

It is concluded that the differences between the three groups with regard to the periodontal support are small. The large amount of crowns and bridges in both the SDA and SDA and RPD groups, and the dental history of these subjects, resulting in SDA, should be taken into account. However, as indicated by the periodontal breakdown of premolars in some subjects with SDA, the combination of an existing severe periodontal involvement and a SDA is considered to be an unfavourable situation.

Introduction

In shortened dental arches (SDA), when molar support is absent, it may be expected that the occlusal forces on the remaining teeth will increase.

Ramfjord and Ash stated in 1983 that 'whether abnormal occlusal forces injure normal periodontal structures or normal or excessive occlusal forces injure already weakened periodontal structures depends (1) on the resistance and response of the tissue to the forces and (2) on the morphological features of the teeth, arches and the supporting structures that resist or modify the forces'. If increased occlusal forces lead to periodontal trauma from occlusion, this co-destructive factor may result in increased mobility of the teeth and alteration of the lamina dura and periodontal space. Vertical alveolar and supporting bone resorption may occur as a result of these alterations (Ramfjord & Ash, 1983).

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In general, when only anterior teeth remain (extreme SDA), there is an increased risk of overloading the anteriors, resulting in pathological spacing and periodontal breakdown. The question arises as to whether a SDA, where anterior teeth and premolar teeth remain, can withstand the occlusal forces. The results of Käyser's (1981, 1984) studies indicated that decreased occlusal support beyond a turning range of 2–4 occlusal units should lead to accelerated periodontal breakdown of the remaining teeth.

The aim of this study was to investigate in more detail the relationship between SDA and periodontal support. This was done by assessing the mobility and relative alveolar bone height of the teeth. A group of subjects with SDA and a free-end RPD in the lower jaw was also included in this study. It was assumed that two types of teeth, each having a specific condition, should receive special attention.

(i) Premolars that are the most posteriorly located and occluding teeth in the dental arch. The increased alveolar resorption in the area posterior to these teeth may affect the alveolar bone height of the posterior tooth (Silness, Hunsbeth & Figenschou, 1973; Plotnick, Beresin & Simkins, 1975). However, reduction of the radiographic level of the bony alveolar crest after the extraction of adjacent teeth was not observed by Grassi, Tellenbach & Lang (1987).

(ii) Premolars that serve as abutment teeth for free-end RPD, because of the presumed periodontal damage to these teeth (Carlsson, Hedegard & Koivumaa, 1962; Monteith, 1984; Berg, 1985; Lappalainen, Koskenranta-Wuorinen & Markkanen, 1987; Markkanen *et al.*, 1987; Tuominen, Ranta & Paunio, 1989). Other authors did not observe this negative effect when favourable conditions were present, i.e. oral and denture hygiene (Bergman, Hugoson & Olsson, 1982; Chandler & Brudvik, 1984; Germundsson, Hellman & Ödman, 1984; Rissin *et al.*, 1985; Bergman, 1987; Isidor & Budtz-Jørgensen, 1987).

Restorations with subgingivally located margins may also have a negative effect on the periodontal health (Silness, 1970; Valderhaug & Birkeland, 1976; Hakkarainen & Ainamo, 1980; Rohner, Cimasoni & Vuagnat, 1983; Fisher *et al.*, 1984; Claman, Koidis & Burch, 1986; Markitziu, 1987; Brunsvold & Lane, 1990). For this reason it was desirable to obtain information about the number of crowns, a substantial number of which had subgingivally located margins, due to the generally extensive amalgam or composite restorations that were present before the crowns were inserted.

Material and methods

In this study three groups of subjects were compared:

(i) subjects with SDA (n=74);

(ii) subjects with SDA provided with free-end RPD (n=25);

(iii) subjects with complete dental arches (CDA, n=72), who represented a control group.

As reported previously (Witter *et al.*, 1989) the subjects with SDA and those with SDA and RPD had a reduced dental arch consisting of the anterior teeth and 3–5 occlusal units (OU) in the posterior area. One occlusal unit is regarded as consisting of a pair of antagonistic premolars, and one molar unit is considered to be equivalent to 2 OU. Figure 1 shows the percentage distribution of the present teeth 13, 14, 15, 16 and 43, 44, 45 and 46, for both the SDA and the SDA and RPD groups.

Figure 2 shows the percentage distribution of the crowns and the abutment function of the teeth 13, 14, 15 and 43, 44, 45, for the three groups.

All subjects were selected from the Dental Clinic of the University of Nijmegen.

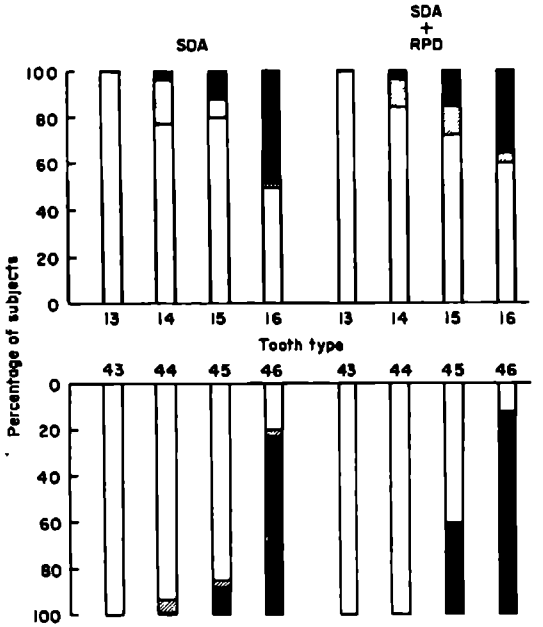

Fig. 1. Percentage distribution of the present teeth (including pontics) in the SDA and SDA+RPD groups, for the teeth 13, 14, 15, 16 and 43, 44, 45, 46: (■)=absent, (▨)=pontic, (□)=present.

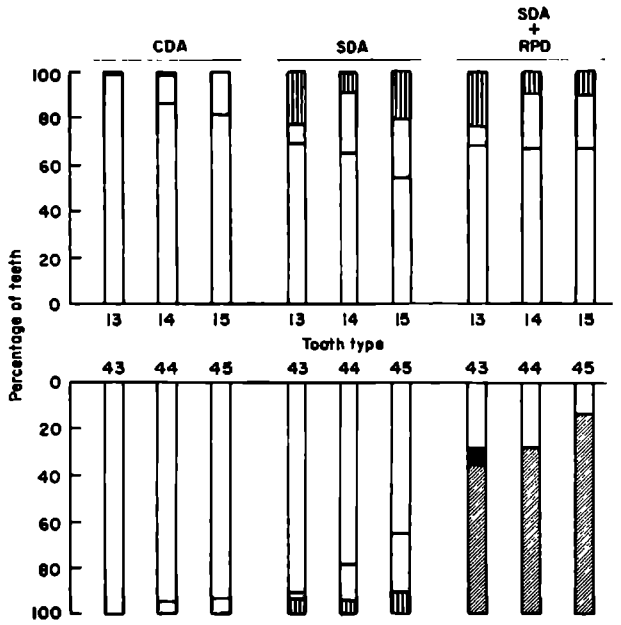

Fig. 2. Percentage distribution of the crowns and the abutment function of the teeth, for the teeth 13, 14, 15 and 43, 44, 45, in the three groups: (■)=crowned and abutment for FPD, (□)=crowned tooth, (□)=tooth without crown, (▨)=abutment for RPD without crown, (■)=crowned and abutment for RPD.

Further details have been reported previously (Witter *et al.*, 1989).

In order to examine the mobility of the examined teeth, the following scale was used (Carranza, 1984):

grade 0, physiological mobility;

grade 1, mobility slightly more than physiological;

grade 2, mobility moderately more than physiological;

grade 3, severe faciolingual and/or mesiodistal mobility combined with vertical displacement.

For assessment of the alveolar bone level of the examined teeth, a relative method was used, which expressed the alveolar bone height (the distance between the alveolar crest and the apex of the tooth) as a fraction of the radiographic tooth length (Björn, Halling & Thyberg, 1969; Sjölien & Zachrisson, 1973; Eliasson, Lavstedt & Ljungheimer, 1986). The crest of the alveolar bone was interpreted as the most coronal level where the periodontal membrane retained its normal width.

An absolute method (measurement of the distance between the alveolar crest and the cementoenamel junction) is superior to a relative method with regard to reproducibility and readability (Albandar & Abbas, 1986). However, it was assumed that, in many cases, the cemento-enamel junction would not be visible, due to overlapping restorations. Furthermore, the cemento-enamel junction on radiographs is not clearly defined on the approximal surface (Theilade, 1960), and is affected by a varying angulation of the central X-ray beam (Sewerin, Andersen & Stoltze, 1987). The total tooth length used by Björn, Halling & Thyberg (1969) as a reference point may be determined more accurately than the cementoenamel junction (Kelly *et al.*, 1975).

In this study, intra-oral radiographs were taken during the recall visits, usually according to the bisecting-angle technique. It should be noted that the paralleling long-cone technique does produce more accurate results (Mourshed & McKinney, 1972; Kelly *et al.*, 1975; Biggerstaff, Phillips & Lexington, 1976; Forsberg, 1987). Although the imperfections of even the most reliable techniques have recently been reported (Benn, 1990), it is assumed that, when compromises must be made, radiographs prepared by means of the bisecting-angle technique yield sufficient relevant information about the periodontal bony support (Lang & Hill, 1977). Alveolar bone height and total tooth length were measured from the radiographs on an X-ray viewer (without magnification), using a compass, and were read to the nearest millimetre on a ruler.

All statistical tests were performed using a two-sided significance level of 5%.

Results

Tables 1 and 2 show the frequency distribution of the mobility of the natural teeth, including the abutment teeth for FPD and RPD, for the three groups.

When comparing the mobility of a tooth (grade 0 vs. grades 1, 2 and 3) between the three groups, using Chi-square tests, the differences were found to be significant for the teeth 13, 15 and 45 (Table 3).

A logistic regression analysis (Table 4) was applied using the following three independent variables: (i) group; (ii) most posteriorly located occluding premolars (terminal) vs. intermediately located premolars; and (iii) abutment teeth for free-end RPD in the lower jaw vs. non-abutment. This analysis revealed no significant differences between the levels of these variables.

Table 5 shows the distribution of the mobility on subject level, according to group. The overall χ^2-test showed a significant difference ($P=0.02$) in the occurrence of the one

Table 1. Distribution of the mobility scores for the natural teeth of the maxilla in the three groups (including abutment teeth for FPD and RPD)

	SDA						SDA+RPD						Control					
	Tooth						Tooth						Tooth					
Grade	11	12	13	14	15	16	11	12	13	14	15	16	11	12	13	14	15	16
0	68	67	68	54	52	35	23	21	23	19	18	14	70	71	72	70	71	72
1	6	5	6	2	4	1	2	1	2	2	1	0	2	1	0	2	0	0
2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	74	72	74	57	57	36	25	22	25	21	19	14	72	72	72	72	71	72

Table 2. Distribution of the mobility scores for the natural teeth of the lower jaw in the three groups (including abutment teeth for FPD and RPD)

	SDA				SDA+RPD				Control			
	Tooth				Tooth				Tooth			
Grade	43	44	45	46	43	44	45	46	43	44	45	46
0	74	68	60	12	25	24	12	3	72	71	72	71
1	0	1	3	0	0	0	3	0	0	1	0	1
2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
Total	74	69	63	12	25	25	15	3	72	72	72	72

Table 3. Significance levels† for the group effects on the mobility of the teeth

	Tooth					Tooth		
	11	12	13	14	15	43	44	45
Group	NS	NS	*	NS	*	NS	NS	***
Control vs. SDA			*		-			NS
Control vs SDA + RPD			NS		NS			**

NS (non-significant), $P>0{\cdot}10$; *$0{\cdot}01<P\leq 0{\cdot}05$; **$0{\cdot}001<P\leq 0{\cdot}01$; ***$P\leq 0\ 001$

† Overall χ^2-tests and pair-wise Fisher's exact test

or more mobile teeth between the three groups. In the SDA and RPD group, there were significantly more subjects with mobile teeth than in the control group ($P=0{\cdot}02$). In the SDA group there was a trend towards more subjects with mobile teeth ($P=0{\cdot}06$).

Table 4. Significance levels† for the mobility of teeth for group effects, location (terminal vs intermediate) and function effects (abutment vs non-abutment)

	Tooth									
	11	12	13	14	15	16	43	44	45	46
Group Control vs. SDA Control vs SDA+RPD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Terminal vs. intermediate	–	–	–	(*)	NS	–	–	NS	NS	–
Abutment vs. non-abutment	–	–	–	–	–	–	–	NS	NS	–

NS (non-significant), $P>0{\cdot}10$; (*) $0{\cdot}05<P\leq 0{\cdot}10$; (–), test not applied for this tooth.
† Logistic regression analysis.

Table 5. Distribution of the subjects in the three groups according to the presence of one or more mobile teeth (teeth 11, 12, 13, 14, 15, 16 and 43, 44, 45, 46)

Group	Subjects without mobile teeth		Subjects with mobile teeth		Total
	n	%	*n*	%	n
SDA	60	81 1	14(*)	18·9	74
SDA + RPD	18	72 0	7 *	28·0	25
Control	67	93 1	5	6·9	72

(*) $0{\cdot}05<P\leq 0{\cdot}10$, *$0{\cdot}01<P\leq 0{\cdot}05$ (pair-wise χ^2-test vs control)

The differences were not significant when the subjects with SDA were compared with the subjects with SDA and RPD.

Table 6 shows the mean relative alveolar bone height measured at the distal side of the premolars. Subjects in the control group showed a greater relative bone height, followed by the SDA group and then the SDA and RPD group. The number (*n*) of teeth measured refers to unusable radiographs, also taking into account the absent teeth for the SDA group and the SDA and RPD group (Fig. 1).

An analysis of covariance (Table 7) with the following three factors (i) group, (ii) terminally located occluding premolars vs. intermediately located premolars, and (iii) abutment for RPD vs. non-abutment, with the continuous covariate age of the subjects, shows that the differences in alveolar bone height were significant for some premolar teeth when the group effect was considered. Significant differences are also found when comparing the most posteriorly located occluding premolars with the intermediately located premolars. In the maxilla in particular the most posteriorly located premolars have lower bone support values.

Premolar abutment teeth for free-end RPD in the lower jaw (data for which are only available for the right side) showed only a slight trend towards lower bone support scores. The most significant effect was that of age (Table 7). During the

Table 6. Distribution of the mean relative bone height measured on the distal side of the premolars

	Tooth							
	14	24	15	25	34	44	35	45
SDA (n=74)								
Mean	0·56	0 56	0·55	0·56	0·61	0·60	0·57	0·59
SD	0·07	0 07	0·08	0·08	0·07	0 05	0·07	0·05
n	53	63	53	54	65	65	57	60
SDA + RPD (n=25)								
Mean	0·55	0·54	0·54	0·54	0·59	0·58	0·55	0·55
SD	0·05	0·07	0·08	0·07	0·09	0·05	0·09	0 06
n	21	20	18	18	24	23	15	15
Control (n=72)								
Mean	0·60	0 59	0·60	0·59	0·62	0·62	0·63	0·63
SD	0·03	0 04	0·07	0·04	0·04	0·04	0 04	0·04
n	63	60	64	62	41	45	66	65

Table 7. Significance levels† for group effects, location (terminal vs intermediate), function (abutment vs. non-abutment) and age effects on the alveolar bone height of the premolars

Correlation	Tooth							
	14	24	15	25	34	44	35	45
Group	**	NS	NS	(*)	NS	NS	(*)	**
Control-SDA	**			NS			NS	**
Control-SDA+RPD	*			*			*	NS
Terminal vs intermediate	NS	**	*	*	NS	**	NS	NS
Abutment vs. non-abutment	—	—	—	—	—	NS	—	(*)
Age	***	***	***	***	*	***	***	***
R^2	0·23	0 27	0·22	0·29	0·07	0·25	0 35	0·42
n	137	143	129	123	129	133	135	140

NS = p>0·10, (*) 0·05<p≤0 10; * 0 01<p≤0 05, ** 0·001<p≤0·01, *** p≤0·001, (—) = test not applied for this tooth.
† Analysis of covariance.

collection of longitudinal data for the SDA group and SDA with RPD group over a period of approximately 5 years, some teeth were lost (Table 8). From the patient records it would appear that existing severe periodontal problems, together with increased occlusal forces as a co-factor, as in the case of SDA, may result in the loss of premolars. This seems to be particularly true of the premolars in the upper jaw, whereas in the lower jaw the premolars were lost due to restorative failures (Table 8).

Table 8. Incidents of tooth loss in the SDA and the SDA+RPD groups, during an observation period of approximately 5 years, in the upper and lower jaw

Age/gender	Lost tooth, and main reason for loss	Radiographic bone support (mm)	
		Mesial	Distal
Upper jaw			
57 (F) *	14 (periodontal)	4	10
57 (F) †	25 (caries)	11	10
53 (F)	24 (periodontal)	6	6
	25 (periodontal)	6	5
48 (F)	14 (periodontal)	4	4
	15 (periodontal)	7	7
	24 (periodontal)	7	7
Lower jaw			
74 (F)	43 (dislodged FPD)	12	12
	45 (dislodged FPD)	11	10
	34 (crown fracture)	12	11
57 (F) †	35 (root fracture) ‡	13	11
56 (F) *	35 (periodontal)	3	6
49 (F)	35 (root fracture) ‡	14	11
43 (M)	35 (root fracture) ‡	10	8

* Same subject.
† Same subjects.
‡ Tooth with post.

Discussion

The results of this study should be interpreted with caution, bearing in mind the fact that approximately 25% of the subjects had a SDA for 0–4 years, 25% for 5–9 years, 25% for 10–14 years and 25% for ≥ 15 years (Witter *et al.*, 1989).

Furthermore, it must be taken into consideration that subjects with a SDA most probably belonged to a dental high risk group leading to a SDA condition. The high number of crowns suggests the same situation (Fig. 2). It may be assumed that this dental history has affected the remaining dentition.

Subjects with SDA do have more mobile teeth and lower alveolar bone scores, on a significant or weak significant level (Tables 4, 5, 6 and 7), indicating that these subjects are still a high risk group, as is also the case with regard to the periodontal condition. However, the high number of crowns (Fig. 2) may have adversely affected these results, because of the subgingivally located margins. Although not entirely convincing, it would appear from this study that the most posteriorly located occluding premolars and premolars serving as abutments for free-end RPD in the lower jaw were risk-bearing teeth (Tables 4 and 7).

The combination of existing periodontal involvement and increased occlusal loading, as would be expected in reduced dental arches, represents a potential risk factor for the loss of teeth. It is therefore stressed that subjects with a SDA should keep the periodontal tissues of their remaining teeth in the best possible conditon.

Longitudinal data are required in order to verify these findings.

Conclusions

The results of this study indicate that subjects with SDA, with or without RPD in the mandible, have more mobile teeth and lower alveolar bone scores.

The combination of increased occlusal loading, as in a reduced dentition, and existing periodontal involvement appears to represent a potential risk factor for the loss of teeth.

Because of confounding variables such as dental history and the interrelated amount of crowns and FPD, longitudinal data are required in order to confirm these conclusions.

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Chapter 8

A six-year follow-up study of the oral function in shortened dental arches. Part I: occlusal stability

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A SIX-YEAR FOLLOW-UP STUDY OF ORAL FUNCTION IN SHORTENED DENTAL ARCHES. PART I: OCCLUSAL STABILITY*

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Summary

In this clinical 6-year follow-up study subjects with shortened dental arches (SDA, n = 55), characterized by the absence of molar support, are compared with subjects with complete dental arches (CDA, n = 52) with respect to occlusal stability. In addition, a small group of subjects with SDA and removable partial dentures in the lower jaw (SDA + RPD, n = 19) is included in this study.

The aim of this study was to describe effects regarding occlusal stability in subjects with SDA during a six year period. The applied parameters for occlusal stability are: number of occlusal contacts in the anterior region, overbite, interdental spacing and alveolar bone support.

The results of this study show that:

(i) SDA do provide durable occlusal stability;
(ii) free-end RPD do not contribute to occlusal stability in SDA;
(iii) SDA with periodontally involved teeth show continuing periodontal breakdown.

Introduction

A shortened dental arch (SDA) is a reduced dentition where the most posteriorly located teeth are absent, resulting in loss of molar support. This condition is considered to be a risk factor for occlusal instability, as extensive and uncontrolled migration of the teeth might occur leading to collapse of the bite (mandibular overclosure) and further breakdown of the dentition (Ramfjord and Ash, 1983; Mohl et al., 1988; Thomson, 1990). This occlusal collapse is also described by Stern and Brayer (1975) as they stated: "Pathological changes of the occlusion may occur when posterior tooth support is reduced or lost". Pointing to the aetiology they noted: "One of the commonest causes of occlusal collapse is the unreplaced loss of the lower first molar. The loss of one tooth, however, does not necessarily lead to occlusal collapse".

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In a paper (Witter, Van Elteren and Käyser, 1987), based on a cross-sectional study of the same subjects as in this study, it was concluded that migration of teeth does occur in subjects with SDA, but within an acceptable level. The question arises whether this migration stabilizes on a certain level as a result of a new equilibrium, or that the process of spacing continues, reaching an unacceptable level, such as anterior bite collapse as the above mentioned authors suggested.

It was also reported (Witter et al., 1991) that subjects with SDA (with or without a free-end RPD) have more mobile teeth and lower alveolar bone scores, indicating negative effects on the periodontal support. Possibly the lower bone scores in SDA do decrease further, reaching after years a critical value. However, it is also possible that the lower bone scores were the result of potentially confounding variables, such as the dental history of the subjects, leading to a SDA. Moreover, the interrelated number of crowns and bridges inserted in these dentitions may have acted as a co-factor (Valderhaug and Birkeland, 1976; Rohner, Cimasoni and Vuagnat, 1983; Albandar, Rise and Abbas, 1987; Yusov, 1991).

In addition it was concluded that free-end RPD do not improve occlusal stability (Witter et al., 1989).

To verify the conclusions of the previous cross-sectional studies the subjects were re-examined after 3-years and 6-years. Data were compared with those of subjects with complete dental arches (CDA), being the control group.

Material and methods

From 1981 till 1985 the subjects of this study were selected from the patients of the dental clinic of the University of Nijmegen. Both the SDA group (n = 74) and the SDA + RPD group (n = 25) had to meet the following criteria:

(i) a remaining dental arch consisting of the anterior teeth and 3-5 occlusal units (OU) in the posterior area; one occlusal unit is regarded as consisting of a pair of occluding premolars, and one molar unit is considered to be equivalent to 2 OU (Fig. 1);

(ii) an acceptable anterior relation, which means that extreme Angle Class II and Class III relations were excluded;

(iii) no missing teeth in the remaining arches, unless replaced by bridges.

A control group (n = 72) was selected meeting the same criteria, with the exception that these subjects should have a complete dental arch (with or without third molars).

The drop-out of the participants of the three groups during the six year follow-up is shown in Table 1. The dentition of 3 subjects of the SDA group and of 2 subjects of the SDA + RPD group did no longer meet the criteria for SDA because of loss of one or more teeth, whereas 1 subject with SDA acquired as yet posterior support after the eruption of third molars.

The subjects of this study were examined by the first author at the start of the study, 3 years afterwards, and 6 years after the start.

All subjects of the SDA + RPD group (n = 19) had a free-end metal frame RPD in the lower jaw, whereas two subjects had also a free-end RPD in the upper jaw. (The data of the RPD in the upper jaw were not incorporated in this study).

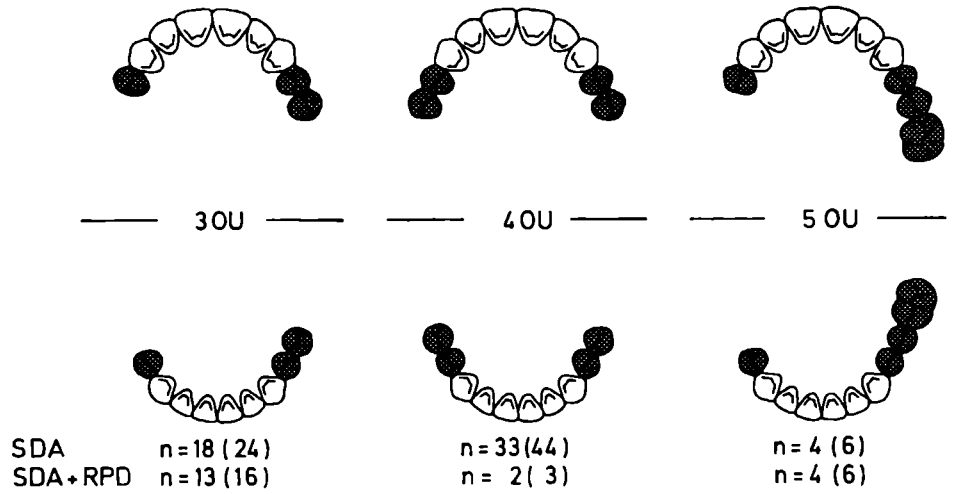

Fig. 1. Representation of the variation of the OU (occlusal units), shown in shaded teeth and the number of subjects (n) of the SDA and the SDA + RPD group at the 6-years evaluation. In parenthesis the number of subjects at the start of the study.

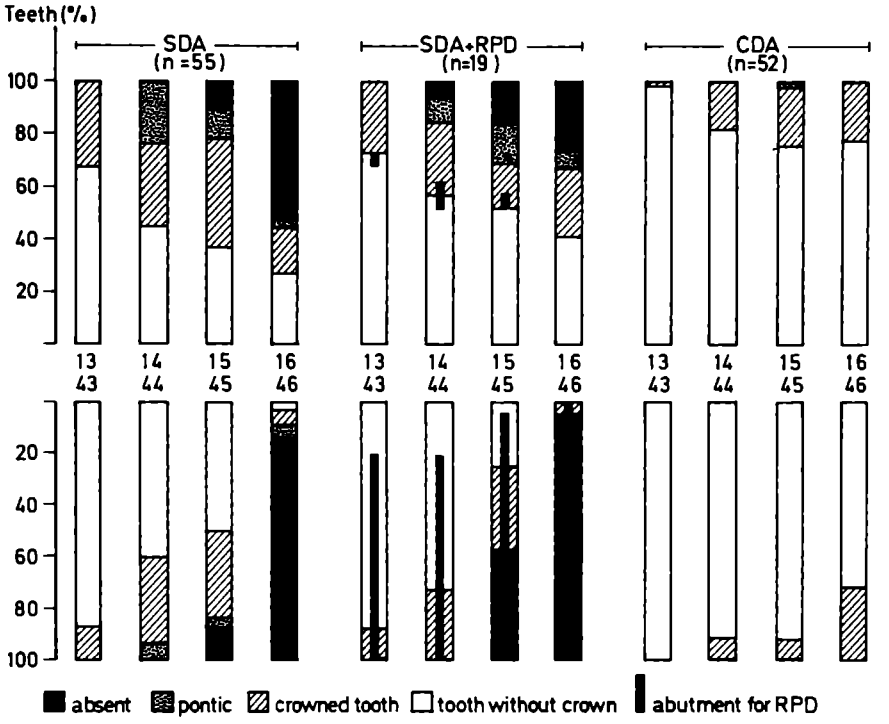

Fig. 2. Presence of the teeth and degree of restoration according to tooth type and presence of a group at start of the study

Table 1. Distribution of the subjects with SDA, with SDA + RPD and with CDA with respect to reason for drop-out during the 6-yr follow-up study.

	SDA		SDA + RPD		CDA	
	n	%	n	%	n	%
subjects at start	74	100	25	100	72	100
drop-out because of:						
- no further treatment on subject's own request[1)]	5	7	2	8	11	15
- no further treatment for other reasons[2)]	3	4	0	0	7	10
- deceased	1	1	0	0	2	3
- no longer meeting criteria for SDA	4	6	2	8	-	-
- 6-yr follow-up not yet available	6	8	2	8	0	0
remaining subjects for 6-yr follow-up	55	74	19	76	52	72

[1)] such as: moving to other area.

[2)] such as: not keeping dental or payment appointments.

During the evaluation period two subjects stopped wearing the RPD in the lower jaw, and two others reported to wear them only occasionally. The data of these subjects were still included in the SDA + RPD group.

As it was expected that the factor age might affect the results, the remaining subjects were divided into two age groups at the start of the study (Table 2). When comparing the subjects < 40 years, no significant differences were found between the three dental groups with respect to age and gender. This was also the case for the subjects ≥ 40 years between the three dental groups.

Table 3 shows the distribution of the subjects with SDA and SDA + RPD according to the number of OU (Fig. 1), the duration of the existence of the SDA, and the duration of wearing a RPD at the start of the study. The SDA + RPD

Table 2. Distribution of the subjects with SDA (n = 55), with SDA + RPD (n = 19) and with CDA (n = 52), according to gender and age (at start of the study).

	age group	n	gender		age (yrs)	
			male	female	mean	SD
SDA	< 40	30	14	16	32	5
SDA	≥ 40	25	8	17	49	7
SDA+RPD	< 40	7	1	6	36	3
SDA+RPD	≥ 40	12	3	9	48	6
CDA	< 40	30	16	14	30	5
CDA	≥ 40	22	10	12	48	5

Table 3. Distribution of the subjects with SDA (n = 55) and with SDA + RPD (n = 19), according to the number of OU (including pontics), the duration of the existence of the SDA and the duration of wearing the RPD (at start of the study).

	SDA		SDA + RPD	
	n	%	n	%
Number of OU:				
3 OU	18	33	13	68
4 OU	33	60	2	11
5 OU	4	7	4	21
Duration of SDA (years)				
0- 4	12	22	3	16
5- 9	12	22	5	26
10-14	18	33	7	37
≥15	13	24	4	21
Duration of wearing RPD (years)				
0- 4	-	-	9	47
5- 9	-	-	5	26
10-14	-	-	3	16
≥15	-	-	2	11

group has significantly less OU in comparison with the SDA group ($p = 0.001$, Chi-square test), and substantial more asymmetrical occluding arches (89% versus 40%).

It must be noted that, as a rule, subjects with SDA as well as subjects with SDA + RPD had a dental history of caries and periodontal disease before acquiring a SDA. This means, because teeth got lost gradually, that there was a more restricted shortening of the arches or there were interrupted dental arches,

prior to acquiring the present SDA condition. Consequently subjects with SDA and with SDA + RPD have had far more restorative treatment, including crowns and bridges (Fig. 2). These conditions may have affected the remaining dentition.

The methods used in this study were described in previous papers (Witter et al., 1987, 1991), so they are summarized just briefly. The presence or absence of occlusal contact was assessed in the intercuspal position (IP) with occlusal registration strips (Artus®, 13 μm thick).

The overbite was measured in millimetres on the incisors 11 and 41 (distance incisal edge 11 to incisal edge 41 in vertical direction). Interdental contact or spacing was measured with metal gauges with thickness of 0.1, 0.5 and 1.0 mm between the teeth of the right side of the mouth. Contact was judged to exist when the 0.1 mm gauge was obstructed in the interdental area. The following scores were used:

0: spacing $<$ 0.1 mm (contact);
1: spacing $\geq$ 0.1 and $<$ 0.5 mm;
2: spacing $\geq$ 0.5 and $<$ 1.0 mm;
3: spacing $\geq$ 1.0 mm.

For the assessment of the alveolar bone level a relative method was used, expressing the alveolar bone height (the distance between the alveolar crest and the apex of the tooth) as a fraction of the radiographic tooth length. The crest of the alveolar bone was interpreted as the coronal level where the periodontal membrane retained its normal width. Bone height and total tooth length were measured from the radiographs (most of them made with the bisecting-angle technique) by means of a compass and were read to the nearest millimetre on a ruler.

For statistical analysis a Repeated Measurement Analysis (Winer, 1971) was applied to investigate:

(i) group effects: differences between the three dental groups (SDA, SDA + RPD, CDA);
(ii) age effects: differences between the two age groups ($<$ 40 yrs, $\geq$ 40 yrs);
(iii) time effects: differences between the three measurements within subjects.

No statistically significant interactions between dental group and age group, between time effect and dental group, between time effect and age group, respectively between time effect, dental group and age group were found when applying the Repeated Measurement Analysis.

All tests were performed with a confidence level of 5%.

Results

The distribution of occlusal contacts in IP according to tooth type is shown in Fig. 3. There are more occlusal contacts in the anterior region for the SDA group $\geq$ 40 years in comparison with the control group $\geq$ 40 years. However, no statistically significant differences were found between dental groups and age groups. Furthermore, no significant changes in occlusal contacts during the 6-year evaluation (time effects) were found. (For the statistical analysis the average percentage of the total of contacts, considering only the four incisors, are taken into account.)

Fig. 4 represents the cumulative percentage of the subjects of the three dental groups with the assessed overbite. The mean overbite is given in Table 4. Repea-

ted Measurement Analysis shows no statistically significant group or age effect, but within the subjects there is a significant time effect ($p < 0.001$). Additional testing (Signed Rank Test, Table 4), within each group shows for the SDA + RPD group and for the CDA group a statistically significant increase of the overbite during the 6-years evaluation period. On the whole one out of eight subjects, both in the SDA and the CDA group has an overbite $\geq$ 6 mm.

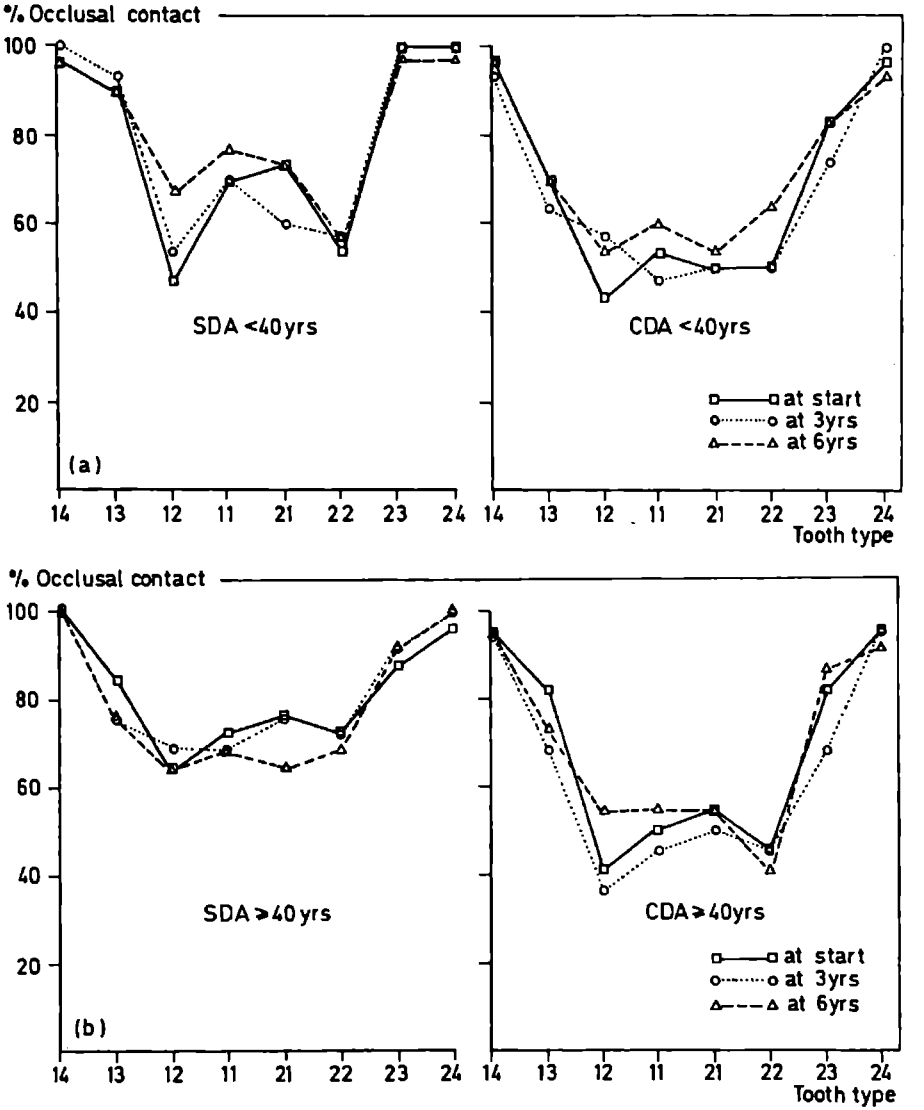

Fig. 3. Graphic representation of the occlusal contacts according to tooth type of the subjects < 40 yrs (a) and of the subjects ≥ 40 yrs (b) for the SDA and the CDA (control) group at start, at 3-yr and at

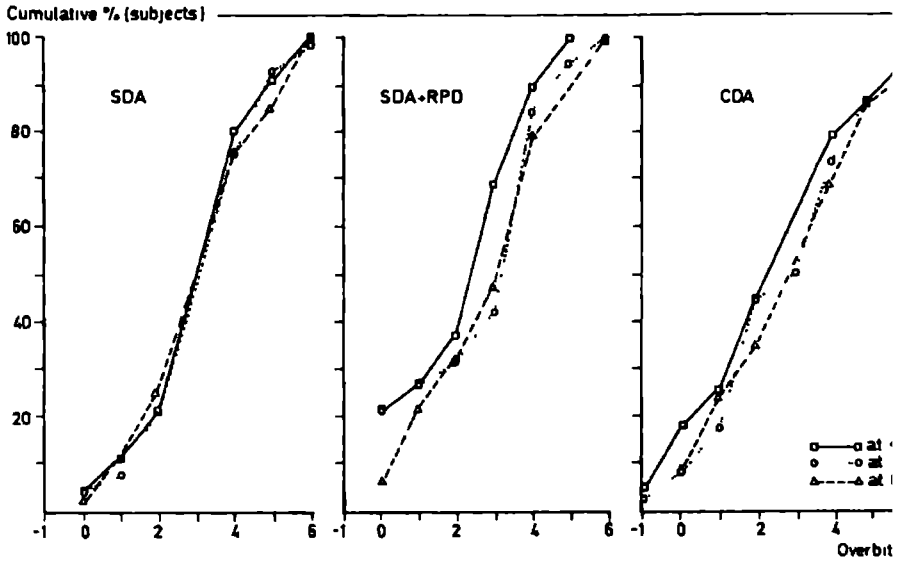

Fig. 4. Cumulative percentage of the subjects of the three grc according to overbite at start, at 3-yr and at 6-yr evaluation.

4. Mean overbite (mm) for the three groups < 40 yrs and ≥ 40 yrs and number of subjects with an overbite ≥ 6 mm at start (0), at 3-yr (3) and 6- yr evaluation (6).

	overbite						overbite ≥ 6				
	0		3		6		0		3		
	mean	sd	mean	sd	mean	sd	n	%	n	%	n
< 40	3.6	1.4	3.8	1.4	3.6	1.6	3	10	2	7	5
≥ 40	3.2	1.5	3.3	1.5	3.4	1.5	2	8	2	8	3
tPD<40	2.6	1.5	3.3	1.6	3.3(*)	1.3	0	0	0	0	0
tPD≥40	2.6	1.8	2.8	2.1	3.3(*)	2.0	0	0	1	8	2
< 40	2.8	2.2	3.2*	2.0	3.3**	2.0	4	13	3	10	3
≥ 40	3.0	2.1	3.4	2.1	3.5*	2.2	3	14	4	18	4

d Rank Test: (*) 0.05 < p ≤ 0.10; * 0.01 < p ≤ 0.05;
aring with ** 0.001 < p ≤ 0.01
start)

The interdental contacts (or spacing) are expressed in an average score of spacing per region, using the earlier mentioned scores. For each region a subject was excluded when two or all three interdental contacts could not be assessed (bridge or splinted crowns). With regard to the premolar region it must be noted that in case of a SDA with only one premolar present, the space 13-14 or 43-44 was scored as the average score. Because there were no statistically significant differences in spacing for the subjects <40 years and the subjects $\geq$ 40 years, the results of both age groups are taken together in Fig. 5.

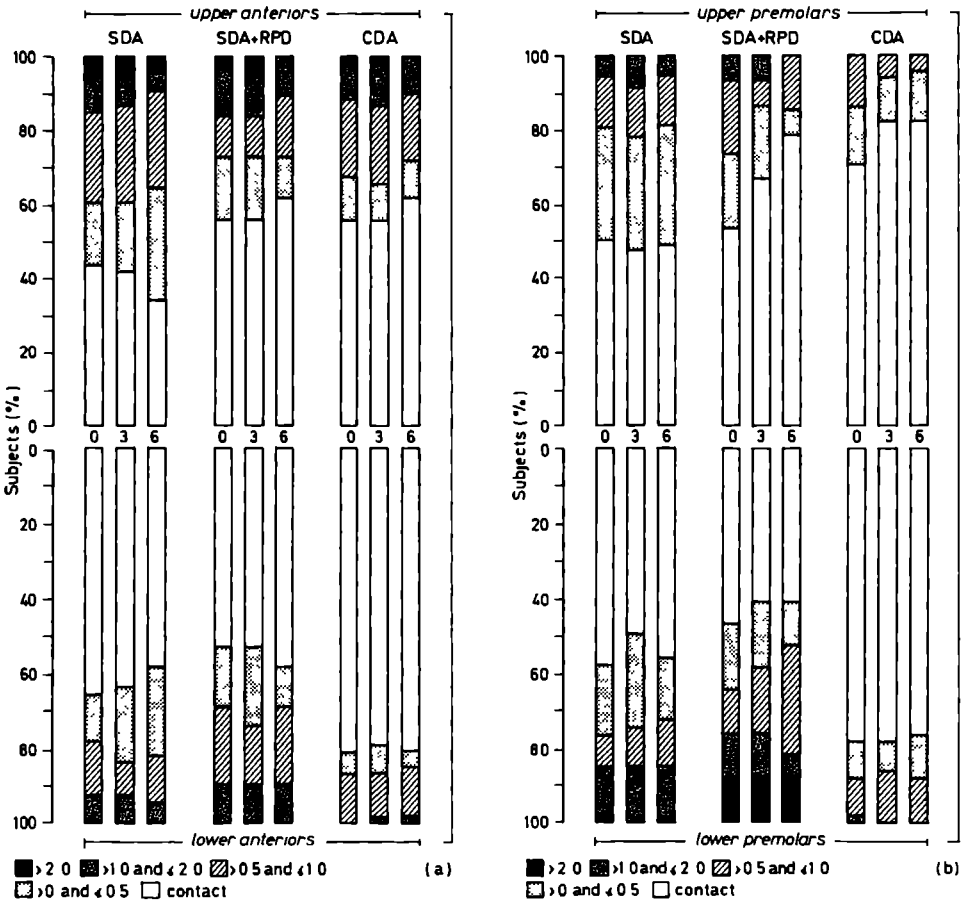

Fig. 5. Distribution of the average interdental contact (or spacing) for the anterior region (a), and for the premolar region (b) at start (0), at 3-yr evaluation (3) and at 6-yr evaluation (6). (The specification of spacing denotes average scores, not millimetres).

For the upper anterior region the Repeated Measurement Analysis shows no statistically significant differences between the groups, nor within the subjects of the groups (time effect), indicating that there is no increase in spacing during the evaluation period in this region. For the lower anterior region a weak significant group effect ($0.05 < p \leq 0.10$) is found: the CDA group has more interdental contact than the SDA and the SDA + RPD group. However, there is no time effect (increase in spacing) during the observation period. In the upper premolar region a significant group effect is found ($0.001 < p \leq 0.01$). The CDA group has more interdental contact and less spacing than the SDA and the SDA + RPD group. Also a significant time effect ($0.001 < p \leq 0.01$) is found, indicating that the SDA + RPD group acquires more frequently interdental contact during the 6-years evaluation, whereas the SDA group remains constant in this respect. The lower premolar region reveals a highly significant difference ($p \leq 0.001$) between the groups, the CDA group having more interdental contact than the SDA and the SDA + RPD group. Nevertheless, there is no time effect within the subjects of the three groups, indicating that the excisting spacing remains constant.

The results for the relative bone height, as measured on the distal side of the premolars, are given in Table 5a for the maxilla and in Table 5b for the mandible. The Repeated Measurement Analysis excludes incomplete data strictly, meaning that only data are used that are available at start, at 3 years and at 6 years evaluation.
For all premolars the bone scores of the SDA and the SDA + RPD group are lower than those of the CDA group; the SDA + RPD group having the lowest scores. These differences are statistically significant for tooth 25 and 34 ($0.01 < p \leq 0.05$), tooth 15 ($0.001 < p \leq 0.01$), tooth 14, 35 and 45 ($p \leq 0.001$). Moreover an age effect is found for the three groups, showing that the subjects $\geq$ 40 years have lower bone scores than the subjects < 40 years. This is significant for allmost all premolars in the maxilla: tooth 14, 15 and 25 ($0.01 < p \leq 0.05$). For the mandible this effect is significant only for tooth 45 ($p \leq 0.001$).

The decrease of the bone scores during the evaluation period (time effect) is significant only for tooth 14 and 25 ($0.01 < p \leq 0.05$), mainly due to a decrease of the bone scores in the SDA + RPD group. In the SDA group these teeth have more constant bone scores. On the whole the decrease of the bone scores in the SDA group is the same as in the CDA group.

Discussion

In the clinical 6-year follow-up period of this study the drop-out was approximately 25% for all three dental groups (Table 1). Considering the reasons it may be assumed that this drop-out has not influenced the results selectively, with the exception of 5 subjects. Their dentition no longer met the definition of SDA because of further breakdown during the evaluation period, whereas 1 subject with SDA acquired posterior support after the eruption of third molars. On this ground these 6 subjects were excluded from the study. At the start of the study there was doubt whether to involve subjects with a poor periodontal condition. Because it was difficult to assess criteria with respect to the periodontal condition, all subjects were included if they met the earlier listed criteria. Consequently, as might have been predictable, in a few cases there was further periodontal breakdown of the dentition. These cases suggest that the combination of existing periodontal involvement and increased occlusal loading, as may be expected in reduced dental arches, represents a potential risk factor for further loss of teeth.

Table 5a. The relative bone height for subjects with SDA, subjects with SDA + RPD, and subjects with CDA, as measured on the distal side of the premolars of the maxilla at start (0), at 3-yr (3) and at 6-yr evaluation (6).

	14			24			15			25		
	0	3	6	0	3	6	0	3	6	0	3	6
SDA < 40 (n = 30)												
mean	0.59	0.58	0.57	0.57	0.56	0.56	0.58	0.58	0.58	0.56	0.55	0.54
SD	0.06	0.06	0.07	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.07	0.08
n*	21	21	21	21	21	21	22	22	22	20	20	20
SDA ≥ 40 (n = 25)												
mean	0.56	0.55	0.55	0.55	0.54	0.54	0.55	0.57	0.57	0.54	0.54	0.54
SD	0.07	0.07	0.06	0.08	0.07	0.07	0.10	0.08	0.09	0.10	0.06	0.06
n*	13	13	13	12	12	12	12	12	12	16	16	16
SDA + RPD < 40 (n = 7)												
mean	0.57	0.56	0.53	0.56	0.55	0.53	0.58	0.57	0.55	0.58	0.56	0.58
SD	0.05	0.06	0.07	0.13	0.11	0.10	0.03	0.05	0.04	0.10	0.06	0.05
n*	6	6	6	4	4	4	3	3	3	4	4	4
SDA + RPD ≥ 40 (n = 12)												
mean	0.53	0.52	0.51	0.55	0.55	0.53	0.52	0.49	0.49	0.54	0.51	0.48
SD	0.06	0.07	0.06	0.04	0.04	0.05	0.07	0.08	0.11	0.06	0.08	0.13
n*	8	8	8	8	8	8	7	7	7	7	7	7
CDA < 40 (n = 30)												
mean	0.60	0.60	0.60	0.59	0.59	0.60	0.61	0.61	0.61	0.60	0.60	0.59
SD	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.07
n*	22	22	22	20	20	20	23	23	23	20	20	20
CDA ≥ 40 (n = 22)												
mean	0.59	0.58	0.59	0.57	0.55	0.57	0.59	0.58	0.57	0.57	0.56	0.57
SD	0.04	0.04	0.04	0.05	0.06	0.04	0.12	0.04	0.04	0.05	0.06	0.07
n*	20	20	20	17	17	17	20	20	20	17	17	17

* The difference with the number of subjects is caused by absent teeth or unreadible radiograph.

Table 5b. The relative bone height for subjects with SDA, subjects with SDA + RPD, and subjects with CDA, as measured on the distal side of the premolars of the mandible at start (0), at 3-yr (3) and 6-yr evaluation (6).

	34			44			35			45		
	0	3	6	0	3	6	0	3	6	0	3	6
SDA < 40 (n=30)												
mean	0.60	0.59	0.59	0.61	0.60	0.60	0.61	0.60	0.60	0.62	0.61	0.60
SD	0.06	0.07	0.08	0.06	0.06	0.06	0.05	0.04	0.04	0.04	0.05	0.07
n*	22	22	22	22	22	22	17	17	17	21	21	21
SDA ≥ 40 (n=25)												
mean	0.64	0.61	0.61	0.59	0.59	0.59	0.57	0.58	0.58	0.57	0.56	0.55
SD	0.10	0.06	0.07	0.06	0.05	0.06	0.06	0.07	0.08	0.05	0.05	0.04
n*	16	16	16	18	18	18	17	17	17	17	17	17
SDA + RPD < 40 (n=7)												
mean	0.61	0.57	0.57	0.61	0.58	0.59	0.56	0.53	0.49	0.61	0.59	0.58
SD	0.08	0.06	0.07	0.07	0.07	0.07	0.10	0.09	0.10	0.03	0.04	0.03
n*	6	6	6	4	4	4	3	3	3	4	4	4
SDA + RPD ≥ 40 (n=12)												
mean	0.56	0.56	0.57	0.57	0.58	0.58	0.53	0.55	0.55	0.53	0.54	0.55
SD	0.06	0.06	0.07	0.04	0.05	0.05	0.11	0.08	0.08	0.04	0.06	0.07
n*	9	9	9	11	11	11	8	8	8	6	6	6
CDA < 40 (n=30)												
mean	0.64	0.63	0.64	0.64	0.63	0.63	0.64	0.63	0.64	0.64	0.63	0.63
SD	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
n*	8	8	8	7	7	7	19	19	19	23	23	23
CDA ≥ 40 (n=22)												
mean	0.60	0.62	0.62	0.62	0.60	0.59	0.63	0.62	0.62	0.60	0.59	0.60
SD	0.04	0.05	0.06	0.05	0.04	0.05	0.04	0.05	0.05	0.04	0.05	0.05
n*	9	9	9	6	6	6	20	20	20	19	19	19

* The difference with the number of subjects is caused by absent teeth or unreadible radiographs.

In the SDA and the SDA + RPD group there is on the whole a trend toward more occlusal contacts in the anterior area, although the overbite remains stable (Fig. 3, Table 4). Significant effects on spacing between the dental groups are only found in the premolar region (Fig. 5). With the exception of the SDA + RPD group no time effects are found, indicating a stable occlusion. This means that adaptive migration after the loss of molars must have taken place soon after extraction. This conclusion is in agreement with the findings of Love and Adams (1971) and Kirschbaum, Kirschbaum and Lenz (1987). Although dealing with both bounded spaces, they also showed that migration after extraction did occur in the period right after the extraction.

The finding that the lower anterior teeth in the SDA group tend to show spacing is interesting. If spacing of the upper anterior teeth does occur as a result of increased load, one might expect the lower anterior teeth to show more interdental contact. An explanation might be that the spacing of the anterior teeth is caused by a reduction of the anterior component of occlusal force when the molars are absent, rather than by an overload in the anterior region. This might be rational, as Southard, Behrents and Tolley (1989) showed that the mean magnitude of the anterior component of occlusal force for a moderate occlusal load (on second molars) was "unexpectedly high". Moreover, especially occluding molars generate large mesially directed interdental forces when occlusal forces are applied (Osborn, 1961). These forces have been related to the mesial inclination of molars, whereas "premolars usually are aligned with their axial centers nearly perpendicular to the occlusal plane" (Jordan, Abrams and Kraus, 1992).

Spacing per se does not indicate a pathological condition. Silness & Rϕyn-strand (1984) found that proximal surfaces without interdental contact had a more favourable periodontal condition and fewer restorations than surfaces with contact. Fernberg, Bakdash and Keenan (1983) found less debris at open contacts. However, they found also an increased probing depth (0.27 mm) and attachment loss (0.48 mm). In the opposite case of crowding it is pointed out that in periodontal patients local crowding and tooth angulation predisposes to increased bone loss (Jensen and Solow, 1989).

With regard to alveolar bone support the SDA group and the SDA + RPD group have lower bone scores than the CDA group. However, a significant time effect, indicating progressive lowering of the bone scores, is found only for tooth 14 and 25, due to a decrease in the SDA + RPD group. This may suggest that the lower bone scores in the SDA group and the SDA + RPD group reflect the dental history of caries and periodontal disease before acquiring a SDA. Furthermore, the high degree of restorative treatment - as shown in Fig. 2 - may have a negative effect on the periodontal condition.

The as good as constant bone scores of the mandibular premolars in the SDA + RPD group confirm that negative side-effects of free-end RPD's, such as periodontal breakdown, can be minimized under favourable clinical circumstances. This finding is in agreement with other studies regarding free-end RPD's (Bergman, Hugoson and Olsson, 1982; Chandler and Brudvik, 1984; Isidor and Budtz-Jϕrgensen, 1990).

When observing the variables: (i) occlusal contact; (ii) overbite; (iii) interdental spacing; and (iv) alveolar bone support, minor changes did occur in both the SDA group and the SDA + RPD group during the 6-year evaluation period.

The findings lead to the conclusion that minor changes do occur, but that a

not take place. In other words: SDA with 3-5 OU, with or without free-end RPD, provide sufficient occlusal stability for a prolonged period.

Conclusions

Within the confinements of this study the following conclusions can be drawn:

(i) SDA, consisting of 3-5 OU, provide durable occlusal stability;

(ii) Minor changes with respect to interdental spacing occur shortly after the extractions leading to a SDA;

(iii) Lower alveolar bone support in the SDA and the SDA + RPD group at the start tends to decrease in the same degree as in the CDA group (controlgroup);

(iv) The combination of existing periodontal involvement and increased occlusal loading, such as in a reduced dentition, appears to be a potential risk factor for further loss of teeth;

(v) Changes with respect to occlusal stability in SDA cannot be prevented by the insertion of free-end RPD.

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Chapter 9

A six-year follow-up study of the oral function in shortened dental arches. Part II: craniomandibular dysfunction and oral comfort

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A SIX-YEAR FOLLOW-UP STUDY OF ORAL FUNCTION IN SHORTENED DENTAL ARCHES. PART II: CRANIOMANDIBULAR DYSFUNCTION AND ORAL COMFORT.

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Summary

In this clinical 6-year follow-up study subjects with shortened dental arches (SDA n = 55), characterized by the absence of molar support, are compared with subjects with complete dental arches (CDA, n = 52) with respect to items concerning craniomandibular dysfunction and oral comfort. In addition, a small group of subjects with SDA and removable partial dentures in the lower jaw (SDA + RPD, n = 19) is included in this study.

Oral comfort is defined using the following criteria: (i) absence of pain and distress, meaning the absence of signs and symptoms of craniomandibular dysfunction, (ii) chewing ability, and (iii) appreciation of the appearance of the dentition in relation to absent posterior teeth. Additionally, complaints about the free-end RPD are described.

It is concluded that:

(i) a SDA (consisting of 3-5 OU) is not a risk factor for CMD and is able to provide long-term sufficient oral comfort,

(ii) free-end RPD (in the lower jaw) in SDA do not prevent CMD and do not improve oral function in terms of oral comfort.

Introduction

Recently oral comfort, as part of the quality of life, is becoming a more important subject. On the one hand oral comfort is related with dental state and dental health, on the other hand it has social and psychological implications. Dental and general satisfaction (Barenthin, 1977; Heyink and Schaub, 1986), psychological well-being (Karuza and Miller, 1987) and self-esteem (Berkey, Call and Loupe 1985) are important aspects of the evaluation of dental treatment, since a reduced dentition or even total edentulousness is not a disabling or fatal condition (Bailit 1987; Ettinger, 1987; Thines, Karuza and Miller, 1987; Meeuwissen, 1992).

In a previous paper, based on a cross-sectional study of the same subjects as in this study, it was concluded that shortened dental arches (SDA) do not provoke

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signs and symptoms of craniomandibular dysfunction (CMD), (Witter, Van Elteren and Käyser, 1988) and that SDA do provide sufficient oral comfort (Witter et al, 1990 a). However, long-term effects were not measured and it was not known whether the results and conclusions had to be adjusted after a prolonged observation. This might be relevant as Christensen and Ziebert (1986) stated that "Extensive loss of teeth, with subsequent abnormal loading of the TMJ, leads to histomorphological, pathological and pathophysiological changes of the intra-articular structures of the TMJ. The severity of the changes increases with increasing age, and with increased periods of observation. In addition, an existing TMJ arthritis is aggravated by loss of teeth. The early changes may be signs of adaptation, within physiological limits, but later changes are signs of disease". Statements like these, indicating a relation between loss of teeth, such as in SDA, and pathology of the TMJ after increased periods of observation, show the need for follow-up studies.

Traditionally, in case of absent posterior teeth, free-end removable partial dentures (RPD) were inserted to extend the dental arches. The negative side-effects of this dental appliance on the surrounding tissues were accentuated in many reports (Carlsson, Hedegård and Koivumaa, 1965; Zarb et al, 1978; Monteith, 1984; Berg, 1985). Recent studies indicate that this biologic price can be minimized by creating favourable circumstances, which means cause-related initial treatment followed by regular recall visits in order to maintain proper oral (and denture) hygiene (Bergman, Hugoson and Olsson, 1982; Chandler and Brudvik, 1984; Rissin et al, 1985; Lappalainen, Koskenranta-Wuorinen and Markkanen, 1987; Isidor and Budtz-Jørgensen, 1990). Negative statements about RPD's, such as "wearing of RPD is a threat to periodontal tissue" (Tuominen, Ranta and Paunio, 1989) may be considered to be out of proportion as the studies they are based on are often biased. For instance in the study mentioned only 8 % of the RPD wearers had RPD's made of a metal framework. However, it also became clear, that when free-end RPD's replace only molars, it is not evident which oral functions are improved and, if so, to what extent. Cross-sectional studies based on the same subjects as in this study indicated that the oral functions are not improved by the insertion of free-end RPD in case of a SDA with 3-5 occlusal units (OU) (Witter et al, 1989). Oral comfort was also not affected in a positive way (Witter et al, 1990 a).

The aim of this 6-year follow-up study was to verify the conclusions of the previously reported cross-sectional studies. For this reason subjects with shortened dental arches (SDA, n = 55) and subjects with shortened dental arches and a removable partial denture in the lower jaw (SDA + RPD, n = 19) were re-examined after 3 years and 6 years and compared with subjects with complete dental arches (CDA, n = 52). As changes related with oral function may develop gradually, a 6-year follow-up period was considered to be a minimum term.
In this clinical study oral comfort was defined using the following parameters:

(i) absence of pain or distress of the stomatognatic system, based on the absence of signs and symptoms of craniomandibular dysfunction (CMD),

(ii) satisfactory masticatory ability, such that the subjects report normal eating habits and no change is required in food selection or food preparation, due to dental impairment,

(iii) acceptable aesthetics, such that the subjects judge the absence of posterior teeth to be hardly visible and, if at all, does not alter their appearance,

(iv) complaints about the free-end RPD and problems or incidents (repair, replacement or no longer using) with these because of the required adaptation to an altered situation.

Material and method

Details of the subjects of this study, dealing with gender, age and the drop-out during the follow-up are described in part I of this study (Witter et al, 1992). The assessment of the objective signs and symptoms of craniomandibular dysfunction has been reported elsewhere (Witter et al, 1988). Briefly, the objective (clinical) examination consisted of:

(i) the assessment of clicking or crepiting of the temporomandibular joint (TMJ);

(ii) the measurement of the maximal mouth opening (MMO).

The information regarding the subjective signs and symptoms of CMD and the aspects aimed at masticatory ability, aesthetics and complaints about the RPD were gathered by questionnaire. The subject's dental records were used in order to compile incidents of the RPD's and the needed after-treatment.

For the statistical analysis of the categorical data a repeated measurement analysis was applied, described by Koch et al (1977). The categorical data were decoded to dichotomous variables: yes (including answers like: sometimes, heavy or unilateral) and no (including dubious). The marginal percentages of the categorical data (i.e. the percentages "yes" at start, at 3-yrs, and at 6-yrs evaluation) were transformed with the logit function to improve the fit of the model. For all variables with the exception of bruxism habits, a linear time effect fitted well. For bruxism no assumption for the time effects is made. For the continuous data a repeated measurement analysis was used as described by Winer (1971).

For both the categorical as well as the continuous data a stepwise procedure is used, starting from the most complete model and then removing the non-significant interactions or effects (factors) step by step. Table 1 enumerates these interactions and effects as used in the analysis. P-values below 5 % are considered to be significant.

Results.

Table 1 gives the results of the analysis of the interactions and effects of the signs and symptoms of CMD, the factors related to CMD, and occlusal attrition. Significant interactions are found between dental group and time effect for both clicking as well as bruxism habits, indicating that the time effects differ among the three dental groups. Because only few subjects reported restricted mobility of the mandible (Table 3) or impaired general health (Table 4), in this study these variables are not appropriate for statistical analysis.

Table 1 Results of effects and interactions of a stepwise analysis of subjective and objective signs and symptoms (S+S) of CMD, and factors related to CMD and occlusal attrition

ffect/ nteraction	subjective S + S			objective S + S		associated factors			attrition
	noises TMJ	pain	restricted mobility	MMO	clicking	bruxism	unilateral/ front chewing	general health	
lental group effect	ns	ns	2)	..	ns	(•)	•••	2)	ns
ge group effect	-	-					-	-	(•)
ime effect	(•)				(•)				•••
ge • group effect		-							-
ge • time effect	-		-		-	-			-
roup • time effect	-				•	•			
ge • group • time effect		-					-		
esiduals -value)	0 47	0 55	2)		0 19	0 20	0 34	2)	

removed interaction or effect (not significant) and left out of consideration in the final model
(•) for the premolars, not significant for upper and lower anterior teeth
not appropriate for statistical analysis because of low frequencies

Fig. 1 shows the percentage of subjects with subjective signs and symptoms f CMD for the three dental groups. Noises of the TMJ did not reveal significant lifferences between the dental groups and age groups. However, probably there is small time effect (weak significant, $0.05 < p \leq 0.10$) for the three dental roups towards more frequently notifying noises during the evaluation period. Regarding pain in or around the TMJ there are no statistically significant differnces between the dental groups or age groups, nor is there a time effect. Only ew subjects in all three dental groups reported a restricted mobility of the nandible.

Fig. 2 reflects the percentage of subjects with objective signs and symptoms f CMD for the three dental groups. The average maximal mouth opening (MMO) eveals significant differences between the three dental groups ($0.001 < p \leq 0.01$). Mean values and SD for the MMO are presented in table 2, showing that he SDA + RPD group has the smallest MMO and the CDA group has the largest MMO. For clicking or crepiting of the TMJ there is an interaction between dental roup and time effect ($0.01 < p \leq 0.05$), indicating that the time effects differ mong the three dental groups (although the differences themselves between the lental groups and age groups are not significant). The following estimates of the verage percentages (with 95 % confidence interval) of the subjects of the three lental groups with clicking or crepiting during the observations are computed by sing the model: in the CDA and the SDA + RPD group clicking remains onstant in approximately 26 % (95 % confidence interval 15 - 40 %) of the ubjects. In the SDA group there is an increase from 21 % (13 - 34 %) at the

start, to 27 % (17 - 39 %) at the 3-years evaluation, to 33 % (22 - 46 %) at the 6-years evaluation.

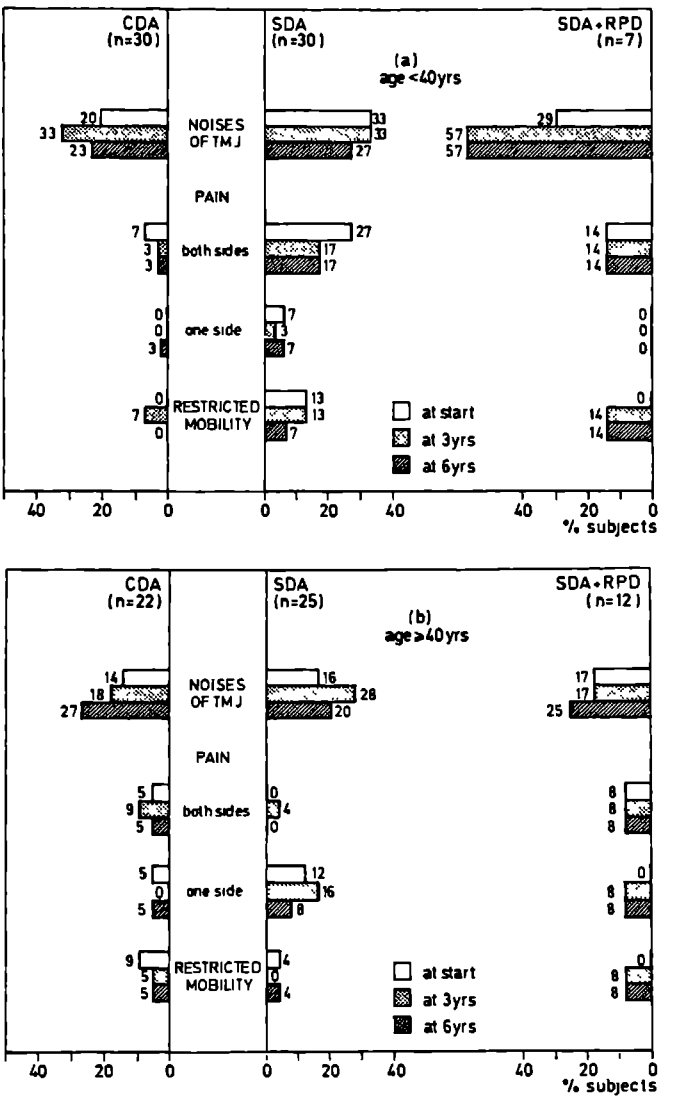

Fig. 1. Percentage of subjects <40 yrs (a) and ≥ 40 yrs (b) with subjective signs and symptoms of craniomandibular dysfunction at start, at 3-yr, and at 6-yr evaluation.

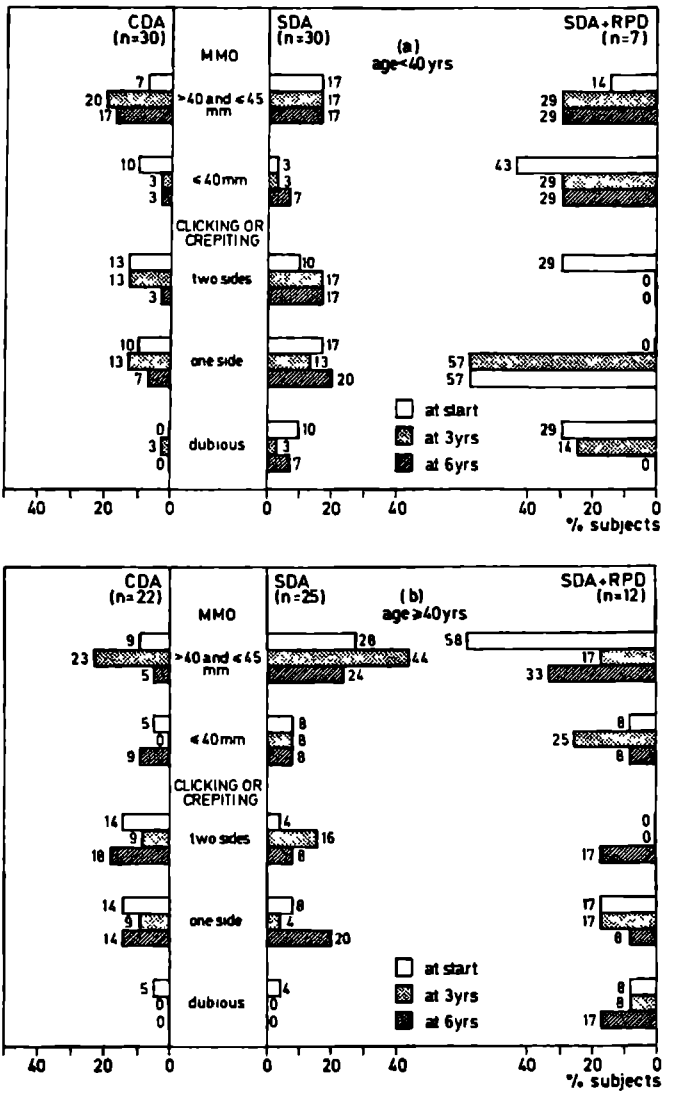

Fig. 2. Percentage of subjects <40 yrs (a) and ≥ 40 yrs (b) with objective signs and symptoms of craniomandibular dysfunction at start, at 3-yr, and at 6-yr evaluation.

Table 2. Average maximal mouth opening (MMO) and SD (mm) at start (0), at 3-yr (3), and at 6-yr evaluation (6), according to dental group (SDA, SDA + RPD and CDA) and age group (< 40 yrs and ≥ 40 yrs).

	0		3		6	
	MMO	SD	MMO	SD	MMO	SD
SDA < 40 (n=30)	51.2	6.7	50.3	7.1	50.5	7.2
SDA ≥ 40 (n=25)	47.8	5.2	46.2	4.8	47.3	4.9
SDA + RPD < 40 (n=7)	43.3	6.9	43.7	7.8	44.4	5.6
SDA + RPD ≥ 40 (n=12)	46.5	5.9	46.0	5.5	47.1	5.9
CDA < 40 (n=30)	51.5	6.7	51.1	5.6	49.7	5.9
CDA ≥ 40 (n=22)	50.5	6.3	50.9	6.3	50.7	6.5

One or more signs and symptoms of CMD are common findings and do occur in high and divergent percentages, as reported by Helkimo, 1979, Clark and Mulligan, 1984 and De Kanter, 1990. It seems to have more sense to describe the number of subjects that is supposed to have really discomfort as a result of CMD. This is done in table 3, using rather arbitrary standards. Due to low frequencies statistical analysis is not possible. However, minor differences between the dental groups remain constant during the follow-up.

Table 3. Number of subjects of the three dental groups, subdivided into age groups, according to severe signs and symptoms (S +S) of CMD, at start (0), at 3-yr (3), and at 6-yr evaluation (6).

	SDA			SDA + RPD			CDA		
	<40 (n=30)			≥40 (n=25)			<40 (n=7)		
	0	3	6	0	3	6	0	3	6
pain in/ around TMJ, heavy or frequent	0	2	1	0	1	1	0	1	1
reported restricted mobility	4	4	2	1	0	1	0	1	1
MMO ≤ 35 mm	0	1	1	1	1	0	1	2	0
Subjects with one or more severe S + S	4	4	2	1	2	1	1	2	1

	SDA + RPD			CDA		
	≥40 (n=12)			<40 (n=30)		
	0	3	6	0	3	6
pain in/ around TMJ, heavy or frequent	0	0	1	0	0	0
reported restricted mobility	0	1	1	0	2	0
MMO ≤ 35 mm	0	0	0	0	0	0
Subjects with one or more severe S + S	0	1	1	0	2	0

	CDA		
	≥40 (n=22)		
	0	3	6
pain in/ around TMJ, heavy or frequent	0	0	0
reported restricted mobility	2	1	1
MMO ≤ 35 mm	1	0	0
Subjects with one or more severe S + S	2	1	1

Bruxism habits, unilateral masticatory function or mastication with the anterioi teeth and impaired general health are supposed to be factors related to CMD. The percentage distribution of the subjects with these factors are compiled in table 4. Fo bruxism a significant interaction ($0.01 < p \leq 0.05$) is found between dental group anc time effect because of the irregular and contrasting time effects between the denta groups. When eliminating these time effects from the model the following estimates o the average percentages (with 95 % confidence interval) of the subjects of the thre dental groups reporting bruxism are computed using the model: for the SDA group 31% (95 % confidence interval 22 - 42 %), for the SDA + RPD group 52 % (34 - 69 %) and for the CDA group 34 % (16-45 %). After eliminating the interaction and the time effect, the subjects with SDA + RPD report significantly more frequently bruxism habits than the other dental groups ($0.01 < p \leq 0.05$). With respect to the chewing side preference the SDA group reports significantly ($p \leq 0.001$) more unilatera chewing or chewing with the anterior teeth. Impaired general health and gastric disorders are not analysed statistically because of low frequencies.

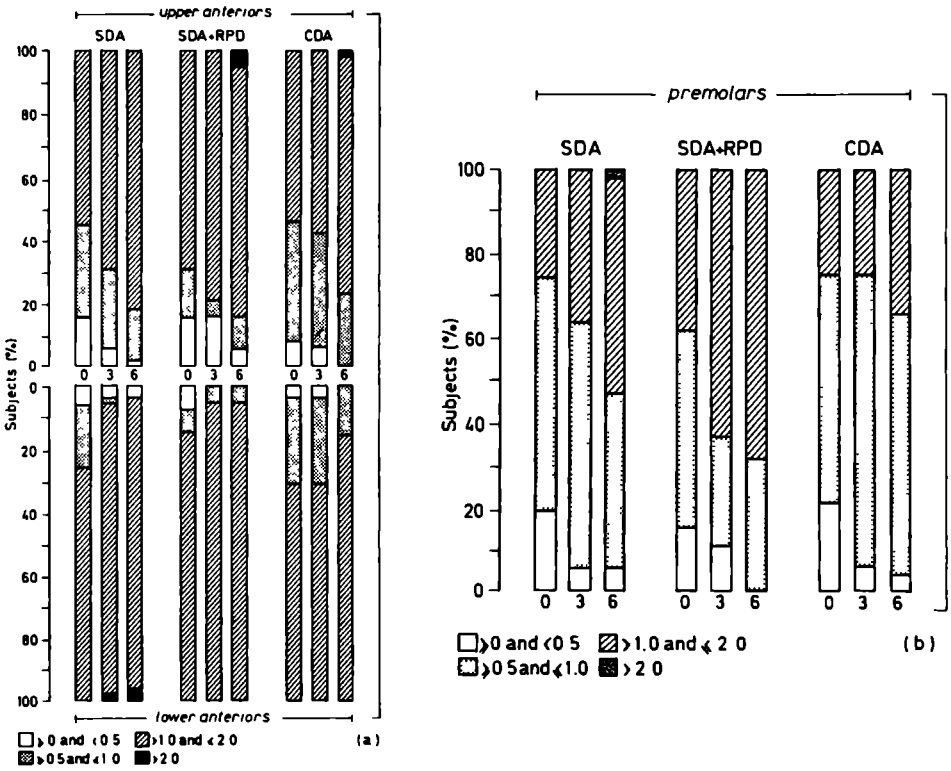

Fig. 3. Distribution of the average degree (scores) of attrition for the upper and lower anterior region (a) and for the premolar regions (b) at start (o), at 3-yr (3), and at 6-yr evaluation (6).

Table 4a. Percentage distribution of the subjects of the three dental groups < 40 years according to factors related to CMD: bruxism, chewing side preference and general health at start (0), at 3-yr (3), and at 6-yr evaluation (6).

	SDA (n=30)			SDA+RPD (n=7)			CDA (n=30)		
	0	3	6	0	3	6	0	3	6
Bruxism									
Sometimes	30	27	30	43	29	71	13	30	20
Often	20	7	7	0	14	0	0	0	3
Chewing side peference									
Left	23	23	23	14	14	43	10	13	20
Right	30	27	37	43	0	43	20	20	13
Anterior teeth	10	10	3	0	0	0	0	0	0
No preference(bilateral)	23	17	23	43	71	14	43	37	40
Not aware of side	13	23	13	0	14	0	27	30	27
General health									
Impaired, other than below	7	3	3	0	14	14	0	0	0
Gastric disorders	10	3	3	0	0	14	0	3	7
Diabetes mellitus	0	0	0	0	0	0	0	3	0
Rheumatoid disorders	0	0	0	14	0	14	3	3	3

Table 4b. Percentage distribution of the subjects of the three dental groups ≥40 years, according to factors related to CMD: bruxism, chewing side preference and general health at start (0), at 3-yr (3), and at 6-yr evaluation (6).

	SDA (n=25)			SDA+RPD (n=12)			CDA (n=22)		
	0	3	6	0	3	6	0	3	6
Bruxism									
Sometimes	16	24	24	42	33	42	23	23	23
Often	4	4	0	8	0	17	5	9	0
Chewing side preference									
Left	28	28	32	25	25	33	27	9	9
Right	32	28	32	25	33	8	14	18	18
Anterior teeth	8	8	8	0	0	0	0	0	0
No preference(bilateral)	24	28	20	50	25	33	41	55	50
Not aware of side	8	8	8	0	17	25	18	18	23
General health									
Impaired,other than below	28	20	16	8	8	8	9	9	14
Gastric disorders	0	4	8	0	0	8	14	18	5
Diabetes mellitus	0	0	0	0	0	0	5	5	0
Rheumatoid disorders	0	0	0	0	0	0	5	5	9

It is to be expected that occlusal attrition might be intensified in SDA. The results show, however, that the differences between the dental groups are not significant . A weak significant ($0.05 < p \leq 0.10$) age effect is found. Subjects above 40 years have more attrition than those under 40 years. Moreover, there is a time effect ($p \leq 0.001$), indicating an increase of occlusal attrition during the evaluation period. Fig.3 shows the distribution of the average degree of attrition (that are the scores as used in the examination) for the separate regions at the three observations.

Table 5 reveals the evaluation with respect to the chewing function and the aesthetic appreciation of the dentition as a result of absent (pre-)molars. About 10% of the SDA and the SDA + RPD group has some problems with the chewing ability. RPD (in the lower jaw) obviously do not improve chewing comfort as they cause some complaints or are not always used. When the RPD is used approximately one out of three subjects has complaints about the RPD. Few subjects with SDA have aesthetic complaints as a result of missing molars.

Table 6 shows that about half of the subjects of the SDA + RPD group function well without extensive after-treatment of the RPD during the 6-years evaluation period. However, one or two rebasings during these six years are considered to be normal.

Table 5. Number of subjects of the SDA and the SDA+RPD group, subdivided into age groups, according to chewing ability, aesthetic evaluation and complaints about the RPD at start (0), at 3-yr (3), and at 6-yr evaluation (6).

	SDA						SDA + RPD					
	<40 (n=30)			≥40 (n=25)			<40 (n=7)			≥40 (n=12)		
	0	3	6	0	3	6	0	3	6	0	3	6
Chewing ability												
Chewing takes too much time	3	3	3	1	1	4	0	0	1	0	0	1
Must swallow food coarsely	1	1	1	1	0	1	0	2	0	0	0	0
Cannot chew all food	0	0	0	0	0	0	0	0	0	0	0	0
Have to use special (prepared) food	0	0	0	0	0	0	0	0	0	0	0	0
Other complaints	0	1	1	0	0	0	1	0	0	0	0	0
Aesthetic complaint (upper jaw)												
Due to missing first molar(s)	1	1	1	1	0	1	-	-	-	-	-	-
Due to missing second premolar	0	0	0	2	2	2	-	-	-	-	-	-
RPD (lower jaw); use												
RPD used occasionally	-	-	-	-	-	-	0	1	0	0	0	2
RPD no longer used(not replaced)	-	-	-	-	-	-	0	0	2	0	0	0
RPD (lower jaw); complaints [1]												
Insufficient retention	-	-	-	-	-	-	2	1	2	1	2	0
Aesthetic complaint	-	-	-	-	-	-	0	0	0	0	0	1
RPD causes pain	-	-	-	-	-	-	0	1	0	0	0	0
More than one complaint	-	-	-	-	-	-	0	1	0	2	1	1

[1]) excluding complaints of 2 subjects no longer using the RPD

Table 6. Number of subjects with SDA and free-end RPD in the lower jaw (n=19), according to the use of the RPD and incidents (re-treatment) during the 6-yr follow-up period.

	number of subjects
No re-treatment of RPD	6
RPD no longer used	1
RPD no longer used, also after making of new one	1
RPD used occasionally	2
New RPD inserted and used	3
Rebase of RPD once	2
Rebase twice anld reconstruction once of RPD	2
Clasp(s) of RPD broken off (no repair)	2
Total	19

Discussion

The design of this longitudinal clinical study is not intended to describe in detail the phenomena that do occur immediately after the removal of posterior teeth. Nevertheless, this study indicates which oral functions have changed after a number of years after acquiring a SDA, and whether these changes progress or stabilise during a 6-year evaluation period.

The results of this study show that SDA do not provoke signs and symptoms of CMD during the 6-year evaluation period (Table 1). From this study it cannot be substantiated that SDA is a risk factor for developing CMD.

The occurrence of signs and symptoms of CMD did not increase, with the exception of a small time effect on noises of the TMJ (for all three dental groups), and for clicking of the TMJ for the SDA group. Obviously changes in the stomathognatic system as a result of SDA, are within the adaptive capacity of the structures of the TMJ (Ramfjord and Ash, 1983; Christensen and Ziebert, 1986; Mohl et al, 1988). The subjects of the SDA group do not report bruxism habits more frequently than the subjects with CDA (Table 4). Furthermore, they do not have significant more occlusal attrition (Table 1, Fig. 3), which could be expected as fewer teeth are present for mastication and to absorb occlusal forces. It is difficult to give an explanation for this finding. Maybe the most important factor is that in modern society the diet and the food preparation do not require intensive mastication (Aukes, Käyser and Felling, 1988). Another reason might be the mutually protected occlusion, which is most often seen in the adult natural dentition (Mohl et al, 1988). This means that the posterior teeth are taken out of contact during lateral and protrusive excursions of the mandible. Mainly the anterior part of the dentition guides the excursions, resulting in functional occlusal wear in this region, both in SDA as well as in CDA. Obviously compensation for missing molars can be performed by the anterior teeth and the premolars without the biologic price of increased attrition.

The subjects of this study report more frequently signs and symptoms of CMD in comparison with the results of a nationwide study in the Netherlands regarding the prevalence of CMD (De Kanter, 1990). It may be assumed that this

can be attributed to the Berkson's confounder, which is potentially present in hospitals (Schlesselman, 1982), and probably also in dental schools as a result of the referral of patients by general practitioners. Another explanation is that subjects without residual dental problems as a rule return to their dentist after treatment in a dental school, whereas those with continuing dental problems stay at the dental clinic. This behaviour - of both referring practitioners and patients - seems to be existing. De Kanter (1990) also found in a pilot-study higher percentages of signs and symptoms of CMD among subjects attending the dental clinic than in the nationwide study. Most striking differences between the results of the nationwide study and this study concern the prevalence of joint sounds and clicking of the TMJ. In the nationwide study about 15 % of the subjects reported noises of the TMJ, whereas in this study, both in the SDA and the CDA group, percentages are around 25. In the nationwide study about 15 % of the subjects have clinically assessed (using a stethoscope) joint sounds or clicking of the TMJ. In this study, using bilaterally palpation of the TMJ during opening and closing movements of the mandible, percentages are about 20-30.

The finding that only few subjects with SDA report complaints about the masticatory ability can be explained by the conclusions of other studies, indicating that subjects with a reduced dentition compensate their compromised masticatory function by chewing with the side with the most teeth (or the longest side), by swallowing larger food particles, and by chewing longer. All three phenomena seem to occur (Oosterhaven et al, 1988). As a result of this adaptation complaints about the masticatory ability just start when "less than 20 well-distributed teeth" are present (Agerberg and Carlsson, 1981). In the SDA group approximately 10 occluding pairs of teeth are present, which obviously meet the criterium of 20 "well-distributed teeth" (Witter et al, 1990 b).

Asymmetrical dental arches of the SDA group are responsible for unilateral chewing (Table 1 and 4). Studies concerning the relation between unilateral function and CMD show divergent results (Boering, 1966; Franks, 1967; Agerberg and Carlsson, 1973; Pond, Narghi and Barnwell, 1986).

Just a few subjects with SDA report complaints regarding the aesthetics due to missing molars or second premolars (table 5). This finding is in agreement with studies indicating that in "an average smile the six maxillary anterior teeth and the first or second premolars are displayed" (Tjan, Miller and The, 1984; Wichmann, 1990), or as Oosterhaven, Westert and Schaub (1989) stated: "Missing (pre-) molars can be seen as a deformity, which is not immediately conspicious"

The subjects with SDA + RPD had more asymmetrical dental arches and fewer OU (Witter et al, 1992). Still the results of this study show that subjects with SDA, wearing free-end RPD in the lower jaw, do not perceive better oral comfort than those without RPD. It seems that they have more signs and symptoms of CMD, especially a restricted MMO (Table 2) and more frequently bruxism habits (Table 4). In a longitudinal study Budtz-Jϕrgensen and Isidor (1990) found also a significant aggreviation of signs and symptoms of CMD after insertion of free-end RPD. It is possible that bruxism is provoked by occlusal interferences created by the clasps of the RPD. Moreover, the clasps can rise when resorption of the alveolar bone is progressing under the saddles, thus causing displacement of the RPD. Plotnick, Beresin and Simkins (1975) found

more resorption of the alveolar bone (in the lower jaw) in subjects wearing a distal-extension RPD than in subjects not wearing a RPD.

It can be concluded that improvement of the oral function by inserting free-end RPD in SDA is just marginal and often questionable as some subjects stopped wearing the RPD (Table 6). Tervonen (1988), studying the prosthetic treatment need among 1600 adults found "greater subjective needs for prosthetic treatment in the anterior and the premolar area than in the molar areas". Lenz (1987) and Budtz-Jørgensen and Isidor (1990) recommand extension bridges for the elongation of dental arches rather than free-end RPD's. Free-end RPD's should not be prescribed "until there are enough missing teeth to impair function" (Spratley, 1988) or the functional capacity of the remaining dentition is deficient (Meeuwissen, 1992). Battistuzzi, Käyser and Kanters (1987) concluded that only in subjects with extreme SDA (when only the anterior teeth remain) the insertion of RPD's improve the oral function.

It should be noted that the number of subjects participating in this study is limited and selected from a dental school population. A study with larger and non-selected groups of participating subjects, preferably in a multi-centered set-up, is recommanded in order to verify the findings of this study.

Conclusions

Within the restrictions of this study it is concluded that:

(i) the absence of molar support is not a risk factor for CMD,
(ii) free-end RPD (in the lower jaw) in SDA do not prevent signs and symptoms of CMD,
(iii) SDA (consisting of 3-5 OU) do provide sufficient oral comfort for a long-term period,
(iv) free-end RPD (in the lower jaw) in SDA do not improve oral function in terms of oral comfort,
(v) free-end RPD (in the lower jaw) in SDA are a frequent cause for re-treatment.

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Chapter 10

General Discussion

10 General discussion

10.1 Methodology

This longitudinal observational study on the oral function of SDA contains a limited number of subjects (chapter 8, table 1). The main reason is that subjects with a genuine SDA (=100% premolar dental arch) were just limited available for selection. Meeuwissen, (1992) found in an observational study among 329 dentate elderly that pure shortened dental arches (SDA) and extreme shortened dental arches (ESDA) without some teeth located posteriorly of the uninterrupted arches, were not present. As stated before (section 1.6) this phenomenon is to be expected as the loss of teeth according to the natural history of the dentition does not always follow the presumed standard pattern, leaving "pure" shortened dental arches. In order to have the opportunity to select a greater number of subjects with a strictly defined dental arch length, a multi-centered study is needed.

Another, more essential reason to give preference to a multi-centered approach is to be able to compare the findings and to verify the conclusions. This might be especially important when subjects are selected from a university dental clinic population such as in this study.

Whether the findings are biased in a positive or negative way by this selection is hard to prove. On the one hand there may be reasons which impair the conclusions, such as: the selected subjects are a result of the "survival of the fittest" phenomenon, eliminating the poor functioning SDA dentitions from participation, and the presumption that patients in a dental school clinic are treated and recalled in a better way than in general practice, resulting in dentitions which are in better condition. On the other hand one may assume that subjects who have problems with their SDA are more motivated to go to a dental school clinic than subjects with the same dental condition but who do not have any problems. This phenomenon may reinforce the conclusions. Also the fact that in most subjects with SDA this dental condition was already present for many years at the start of the follow-up may reinforce the conclusions.

10.2 Main results

Firstly, it can be concluded that a SDA, consisting of the anterior teeth and between three-five occlusal units posteriorly, can meet the functional demands for a prolonged period (Chapters 8 and 9). Though minor migration of the teeth does occur, SDA do provide sufficient occlusal stability. There is no anterior bite collapse (chapter 2 and 8).

As SDA do provide sufficient mandibular stability, the absence of molars appears not to be a risk factor for CMD (Chapters 3 and 9). This study shows that it is necessary to specify "posterior support" into molar support and premolar support. Recent studies (Carlsson & Droukas, 1984; Pullinger, Seligman & Solberg, 1988; Kirviskari, Alanen & Jämsä, 1989; De Kanter, 1990; Mohl, 1990; Schiffman, Fricton & Haley, 1992) indicated that occlusion has a minor role in the aetiology of CMD. A defective occlusion, mandibular instability and unilateral function are considered to be just potential co-factors in the multi-causal aetiology of CMD.

Moreover, SDA do provide sufficient oral comfort in terms of signs and symptoms of CMD, aesthetics, and masticatory ability (Chapters 5 and 9). Only a few subjects report complaints and most of them judged their problems to be "acceptable" or just of minor importance. With respect to CMD, De Kanter (1990) concluded that the number of present teeth is not correlated with signs and symptoms of CMD, except when only the anterior teeth remain.

When considering the findings of this study and the drop-out of subjects during the follow-up, the most serious and critical risk factor of the SDA condition is the periodontal state (Chapters 7 and 8). Probably this is true for all dentitions, reduced as well as complete. However, subjects with a SDA may have a poor periodontal condition as a consequence of the dental history, leading to the SDA condition. In addition, the high degree of restorative treatment in the SDA group may have had a negative effect on the periodontal tissues (because of subgingivally located margins of restorations), and this influence may continue. However, during the 6-years evaluation period the pure SDA effect on the periodontal condition is found to be limited, as the alveolar bone scores in the SDA group tend to decrease in the same degree as in the control group. The drop out of the subjects during the follow-up period indicate that the combination of an existing severely periodontal involvement and increased occlusal loading is a potential risk factor for further loss of teeth. This conclusion is in agreement with the conclusions of Ramfjord & Ash (1981), considering injuries to the periodontal tissues as a result of occlusal forces and periodontitis in a co-destructive relationship. Another interpretation of the progressive periodontal breakdown in some subjects with SDA is that these subjects have had periodontal involvement, which was not limited to the molar area, but was generalised in character. Existing periodontal breakdown is a risk factor for further breakdown (Johnson et al, 1988; Papanou and Lindhe, 1992). Lavstedt, Bolin and Henrikson (1986) concluded that "the difference (decrease) in alveolar bone height is a function of the initial bone loss".

An important finding is that in a SDA, consisting of 3 to 5 OU, a free-end RPD (in the lower jaw) does not improve the oral function in terms of occlusal stability and oral comfort (Chapters 4, 5, 8 and 9). A dental arch extended with a RPD requires intensified efforts of the subjects to reach and maintain adequate oral hygiene (Bergman, 1987; Markkanen et al., 1987; Tuominen, Ranta & Paunio, 1987). The results of this study confirm the conclusions of other studies that free-end RPD's require much re-treatments and give cause to adaptation problems (Chandler & Brudvic, 1984; Budtz-Jørgensen & Isidor, 1990; Cowan et al., 1991). The fact that free-end RPD's are often discarded by the patient should be taken more seriously in prosthodontic treatment planning (Käyser, Witter & Spanauf, 1987; Spratley, 1988). The findings of this study indicate that in case of a SDA, consisting of 3 to 5 OU, the insertion of a RPD often is an example of prosthetic overtreatment.

10.3. Clinical implications

10.3.1. Shortened dental arches versus tooth bounded spaces

Loss of teeth results in a SDA or tooth bounded open spaces (interrupted dental arches). Tooth bounded open spaces have more possibilities for migration of the remaining teeth than SDA, namely mesially and distally of the open space. The most frequent and most serious migration is found as mesially tilting of the distally remaining teeth, followed by distally tilting of the mesially located teeth (Kirschbaum, Kirschbaum & Lenz, 1987). Vertical migration or overeruption of more than 2 mm seems to occur in approximately 5% of the cases (Love and Adams, 1971).

Based on clinical observation the impression exists that overeruption is more seen in tooth bounded spaces than in SDA. This may be explained by the role of the tongue. It is assumed that in SDA interposition of the tongue prevents overeruption. In tooth bounded spaces interposition of the tongue in the open spaces is often hindered by the teeth, resulting in more horizontal and vertical migration. The finding that in SDA migration of the remaining teeth is small, adaptive and self-limiting (Chapter 8), means that occlusal interferences hardly occur. This is in contrast with the consequences of migration in tooth bounded spaces, which often lead to occlusal interferences, necessitating treatment.

Overeruption of unopposed posteriorly located teeth in SDA was not investigated in this study. As this vertical migration may have clinical implications, research of this phenomenon is justified.

10.3.2 The SDA concept

The results of this study do support the SDA-concept as presented in chapter 1 (section 1.2), with regard to the optimal and especially the suboptimal functional level (Table 1-2). In high risk groups and subjects with a broken down dentition the molars may be regarded indirectly essential as they are needed for the long-range stability of the anterior and premolar regions. This means that in dental care programmes the molars should get the same priority as the anterior teeth and the premolars as long as there are no limiting factors. Limiting factors may emerge resulting in a situation in which adequate care for all the teeth is neither possible nor affordable due to general, dental or financial restrictions (Pilot, 1986; Sheiham, 1991). Then priorities have to be set, meaning concentration of the available and affordable dental care on the anterior and premolar regions in order to maintain a suboptimal but still satisfactory functional level.

In other words, to maintain a healthy natural functioning dentition for life means in high risk groups: the ultimate preservation of a premolar dental arch, implicating the preservation of molar support until a certain age. What age? Though this study shows a premolar dental arch to be durable, the follow-up was limited to 6 years. Longer and more follow-up information is needed to support or adjust the age ranges in table 1-2.

In summary, when a SDA is considered to be a treatment option, subjects should meet the following criteria:

(1) major problems (caries, periodontal disease) confined mainly the molar regions,
(2) good prognosis of the anterior and the premolar regions,
(3) limited possibilities for restorative care.
(4) no contra-indications, such as young age

10.3.3 Limited treatment goals

As stated before (Chapter 1), the traditional approach dictating always restoration of missing teeth and molar support is being challenged since many years.
Treatment goals are changing (Table 10-1). As a result of prevention more people retain their teeth at an older age. In case prosthetic treatment is required, patients in general do prefer fixed appliances, which are also to be preferred from a periodontal point of view.

Table 10-1. Traditional treatment approach versus current approach in high risk groups.

	traditional	current
Aim	preservation of complete dental arches	preservation of functional dental arches
Basis	mechanical and morphological concepts	functional and problem solving concepts
Characteristics	replace missing teeth always restore missing molar support always may lead to overtreatment options for fixed appliances usually costly	consider limited treatment goals using: . problem solving approach . SDA concept avoid overtreatment more possibilities for fixed appliances

Limited treatment goals or restoring a dentition partially (Fig. 1-2) often eliminates the traditional indication for RPD, especially in SDA. The findings of this study show the very limited added value in function of RPD in SDA.

By limiting the treatment goals there are more possibilities for fixed reconstructions, both tooth- as well as implant supported. Less complicated fixed appliances cost less and are more durable (Käyser, 1993).

The problem oriented approach and the SDA concept are the main tools to realize limited treatment goals.

10.4 Concluding remarks

1. Oral functional demands change with time and vary between individuals; they may be satisfied with less than 14 occluding pairs of teeth. This means that there is a need for research into flexible and age related occlusal concepts for high-risk groups.

2. The shortened dental arch concept, based on the natural pattern of tooth loss, is a biologic founded example of a problem solving approach.

3. The patient's subjective oral functional needs and well-being should be the starting-point for restorative treatment.

4. High risk groups in relation to tooth loss should be identified as soon as possible in order to set priorities timely, aiming at the preservation of a natural functional dentition in old age.

5. Out of date prescriptions and fee schedules, based on the traditional restoration of lost form, are strong barriers to change in treatment concepts.

6. The problem solving approach and the shortened dental arch concept are main keys to limit treatment goals.

Further research in the field of SDA is needed as there are still several unanswered questions:
- the problem of overerupted teeth (section 10.3.1)
- the durability of the stability in SDA after 10 years or longer (section 10.3.2)
- until what age is preservation of molar support really needed?
- a cost-benefit analysis of the SDA concept in comparison with traditional treatment concepts.

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Summary

The subject of this thesis is to study the long-term relation between shortened dental arches (SDA) and oral function. SDA are defined as a reduced dental arch consisting of a complete anterior region and between three to five occlusal units (OU).

In chapter 1 the functional problems related to the SDA condition are described. They concern: stability of the dentition, changes in the temporomandibular joint (TMJ), and functional comfort. The prime objective of this study is to investigate whether a SDA can provide sufficient and durable oral function. A derived aim is to investigate the added value of free-end RPD to extend SDA.

The subjects for this study were selected from the patient population of the dental school of the University of Nijmegen. Three groups were selected and followed during six years:

- a SDA group (n = 74)
- a SDA group provided with RPD (n = 25)
- a control group with complete dental arches (n = 72)

The subjects were investigated every three years. Oral function was transformed in measurable parameters, such as masticatory ability, interdental spacing and attrition. When it is shown that reduced dentitions can function in an acceptable and durable way, goals for restorative treatment in high risk groups can be limited.

In chapter 2 the consequences of the absence of molar support for the remaining dentition are investigated by comparing the SDA group and the control group at the start of the follow-up. This chapter focusses on the occlusal stability of a SDA. Due to migration of the premolars in a posterior direction, the vertical dimension may decrease and consequently the overbite should increase. In addition it may be expected that the number and intensity of occlusal contacts between the anterior teeth increase, resulting in interdental spacing in the upper anterior region.

It is concluded that minor migration of the teeth in SDA does occur, but within an acceptable level. Longitudinal data are needed in order to verify whether this migration continues or is self-limiting due to the establishment of a new and stable situation.

In chapter 3 the same groups of subjects are compared at the start of the study with respect to signs and symptoms of craniomandibular dysfunction (CMD). The subjective (anamnestic) examination comprised questions related to pain in or around the TMJ, noises within the TMJ, and mobility of the mandible. The objective (clinical) examination consisted of the registration of clicking or crepiting of the TMJ by bilateral palpation during opening and closing of the mouth and of measuring the maximal mouth opening. The results suggest that the absence of molar support does not provoke signs and symptoms of CMD in this population. The presence of bilateral premolar support seems to provide sufficient mandibular stability. As sequelae of the SDA condition might be progressive in character, longitudinal data are recommanded.

The subject of chapter 4 is the effect of free-end removable partial dentures (RPD) on the oral function in SDA. 19 Subjects of the SDA group had worn a RPD in the past. This group was separated in order to find out why these subjects decided not to continue wearing their RPD. Subjects with a RPD previously reported more complaints about their dental appearance as well as about their masticatory ability. Obviously these problems were not solved adequately by the RPD, as they stopped wearing them. No evidence is found that a free-end RPD does improve oral function in case of a SDA with 3 to 5 OU. It is concluded that the factor "dentist" plays a large role in the prescription of a free-end RPD, and that patient-related factors seem to be the major reason to stop wearing a free-end RPD.

In chapter 5 oral comfort as perceived by the subjects is studied. The data of subjects with SDA, and of subjects with SDA + RPD were compared with those of the control group.

Oral comfort was defined as the absence of pain or distress of the stomatognathic system, satisfactory masticatory ability, and acceptable aesthetics. It was expected that incidents with a free-end RPD, such as repair, rebasing or replacement, may affect oral comfort negatively because of the required adaptation to an altered situation. The conclusions of this study are that SDA (consisting of 3-5 OU) appear to provide sufficient oral comfort. Free-end RPD (in the lower jaw) do not contribute to oral comfort in these cases. On the contrary, subjects with a RPD reported more bruxism habits. Moreover, free-end RPD do

need much re-treatment, as appeared from a retrospective study of the patient files of 23 subjects over a period of 6.9 years. A substantial part of the subjects (5 out of 23) decided not to wear the RPD any longer.

In chapter 6 an explanation is given for the finding that just 10 % of the subjects with SDA reported complaints about impaired masticatory ability. Masticatory ability is the subjective self-assessment of subjects concerning their chewing capacity and chewing comfort. Based on a literature review it is concluded that this finding is in agreement with other studies. In general the masticatory ability is sufficient as long as 20 or more "well-distributed" teeth remain, such as in SDA. A SDA condition does not lead to a shift in food selection. In present-day society, economical and sociopsychological factors are believed to be more important factors regarding the food selection than dental factors, such as the state of the dentition.
Masticatory performance in this study is defined as the objectively assessed capacity of the dentition to reduce food particles. It appears that a SDA affects the masticatory performance more than the masticatory ability. A relation between poor masticatory performance and gastric disorders, dietary inadequecy or deterioration in general health could not be substantiated in the literature.

Chapter 7 concerns the periodontal support in SDA, using tooth mobility and the relative alveolar bone height on radiographs as parameters.
The results indicate that subjects with a SDA, with or without a RPD, have more mobile teeth and lower alveolar bone scores. Terminally located premolars have a higher risk than intermediately located premolars in this respect. The same result is found for abutment teeth for free-end RPD. Incidents of tooth loss in the SDA and SDA + RPD group indicate that the combination of increased occlusal loading and existing periodontal involvement is a risk factor for progressive periodontal breakdown.
Because of confounding variables such as the dental history, resulting in the SDA condition, longitudinal data are needed in order to clarify these effects.

Chapter 8 comprises the findings regarding migration of teeth and periodontal support at the start of the study, at the 3-yr, and the 6-yr follow-up. In the SDA and the SDA +

RPD group there is a trend towards more occlusal contacts in the anterior area during the evaluation period although the overbite remains stable. With respect to interdental spacing no time effects are found in the groups, with the exception of the SDA + RPD group. These findings indicate that after some adaptive migration a new equilibrium results in a stable occlusion in the SDA group.

With respect to alveolar bone support the situation is more complicated. On the one hand, as illustrated by the drop-out of some subjects due to loss of one or more teeth during the evaluation period, SDA with existing serious periodontal involvement can result in a continuing periodontal breakdown. On the other hand, when comparing the three dental groups, a significant time effect, indicating progressive decrease of the bone scores is found only for tooth 14 and 25, mainly in the SDA and RPD group. This finding suggests that the lower bone scores in the SDA and the SDA + RPD group reflect the dental history of the subjects, resulting in acquiring an SDA condition.

Based on the findings of the follow-up study it is concluded that SDA with 3-5 OU, with or without free-end RPD, provide sufficient occlusal stability for a prolonged period.

In chapter 9 the results concerning signs and symptoms of CMD and the perceived oral comfort at the start, at the 3-yr, and the 6-yr re-examination are described.

The findings indicate that SDA (consisting of 3-5 OU) do provide sufficient oral comfort for a long term period and that the absence of molar support is not a risk factor for signs and symptoms of CMD.

Free-end RPD (in the lower jaw) in SDA do not improve oral function; they are a cause for frequent re-treatment.

The methodology and the main results are discussed in chapter 10; besides some clinical implications are presented. A multi-centered research design is advocated for clinical studies of this type.

The results of this study do support the SDA-concept with regard to the assumption of optimal and suboptimal functional levels (Table 1-2). This means that in high risk groups treatment goals can be limited, leading to many clinical advantages. Oral functional demands change with time and may be satisfied with less than 14 occluding pairs of teeth, implicating a change in treatment concepts. Limited treatment goals in high risk groups

are based on a problem oriented approach and the shortened dental arch concept. However, the question until what age molar support is required, remains to be answered. Besides, additional research is needed especially into the cost-benefit aspects of limited treatment goals.

Samenvatting

Het onderwerp van dit proefschrift is de relatie op langere termijn tussen verkorte tandbogen (VTB's) en gebitsfuncties. VTB's zijn gedefinieerd als tandbogen, die bestaan uit de frontelementen en aansluitend daaraan drie tot vijf occlusale eenheden (OE).

In hoofdstuk 1 worden de functionele problemen, die in verband worden gebracht met VTB's, beschreven. Deze hebben betrekking op de stabiliteit van de dentitie, veranderingen in het kaakgewricht en het orale comfort.

Het primaire doel van deze studie is te onderzoeken of een VTB kan voorzien in voldoende en duurzaam functioneren van het gebit. Een afgeleide doelstelling is om bij VTB de toegevoegde waarde van vrij-eindigende partiële prothesen (PP) aan de gebitsfuncties te onderzoeken.

Voor deze studie werden patienten geselecteerd van de Tandheelkunde Kliniek van de Universiteit te Nijmegen. Drie groepen werden geformeerd en gedurende 6 jaar gevolgd:

- een VTB groep (n=74)
- een VTB + PP groep, die een partiële prothese droeg (n=25)
- een controle groep met complete tandbogen (n=72).

De personen van deze drie groepen werden onderzocht bij de aanvang van de observatieperiode, vervolgens na drie jaar en na zes jaar. De orale functies werden vertaald in parameters zoals de kauwfunctie, diasteemvorming en attritie.

Als wordt aangetoond, dat gereduceerde dentities op een acceptabel niveau langdurig kunnen functioneren, dan kunnen de doelstellingen bij restauratieve behandelingen worden beperkt. Dit is van belang bij de behandeling van risicogroepen.

In hoofdstuk 2 zijn de gevolgen beschreven van het ontbreken van de steun van de molaren voor de restdentitie. Hiervoor zijn de VTB groep en de controle groep met elkaar vergeleken aan het begin van de studie. Ten gevolge van migratie van de premolaren in distale richting kan de verticale dimensie afnemen en de overbeet toenemen. In deze situatie is het te verwachten dat in de frontstreek het aantal occlusale contacten, alsmede de intensiteit ervan, zal toenemen. Dit kan diasteemvorming in het bovenfront tot gevolg hebben.

Op grond van de resultaten wordt geconcludeerd, dat er weliswaar een geringe migratie van de gebitselementen optreedt, maar dat dit binnen acceptabele grenzen blijft. Deze migraties kunnen echter in de loop van de tijd doorgaan en verergeren. Het kan ook zo zijn dat dit proces gelimiteerd is na het tot stand komen van een nieuw occlusaal evenwicht. Daarom zijn longitudinale gegevens noodzakelijk.

In hoofdstuk 3 worden dezelfde groepen met elkaar vergeleken voor wat betreft symptomen van craniomandibulaire dysfuncties (CMD). Het subjectieve (anamnestische) onderzoek omvatte vragen met betrekking tot pijn in of rond het kaakgewricht, geluiden (knappen) binnen het kaakgewricht en de beweeglijkheid van de onderkaak. Het objectieve (klinische) onderzoek bestond uit het registreren van knappen of crepiteren van het kaakgewricht door dit aan beide zijden te palperen gedurende de openings- en sluitbeweging van de onderkaak. Ook werd de maximale mondopening gemeten.

De gevonden resultaten duiden erop, dat afwezigheid van steun van de molaren bovengenoemde symptomen van CMD niet provoceert. De aanwezigheid van de steun van de premolaren links en rechts, zoals in een VTB, lijkt voldoende mandibulaire stabiliteit te geven.

Omdat de gevolgen van een VTB ook op dit punt progressief kunnen zijn, is longitudinale vervolging noodzakelijk.

Het effect op de gebitsfuncties van een vrij- eindigende PP bij een VTB wordt beschreven in hoofdstuk 4. Van de VTB groep hadden 19 personen in het verleden een PP gedragen. Zij werden als een afzonderlijke groep beschouwd met het oogmerk te achterhalen waarom ze besloten hadden de PP niet langer te dragen. Wellicht konden uit de bevindingen van deze groep door een vergelijking met de groep, die de prothese wel waren blijven dragen (de VTB + PP groep), indicaties voor deze voorziening worden geformuleerd. Het bleek dat diegenen die hun partiële prothese niet meer droegen, meer klachten hadden over de esthetiek en over de kauwfunctie. Kennelijk had hun PP in het verleden deze problemen niet naar tevredenheid opgelost, daar ze de prothese niet meer droegen. Aanwijzingen, dat een vrij-eindigende PP bij een VTB de gebitsfuncties verbetert, zijn niet gevonden.

De conclusie is, dat bij het indiceren van een vrij-eindigende partiële prothese, de tandarts een belangrijke rol speelt. Factoren, die bij de patiënt zijn gelegen, lijken verantwoordelijk voor het besluit om de prothese niet langer te dragen.

In hoofdstuk 5 wordt het orale comfort, zoals dat werd ervaren door de personen van de verschillende groepen, beschreven. De gegevens van de personen met een VTB en van de personen met een VTB + PP, werden daartoe vergeleken met die van personen met complete tandbogen.

Oraal comfort werd gedefinieerd als de afwezigheid van pijn en ongemak van het tandkaakstelsel (gerelateerd aan symptomen van CMD), voldoende kauwfunctie en acceptabele esthetiek. Verondersteld werd dat voorvallen met de vrij-eindigende prothese, zoals reparaties, rebasingen of complete vernieuwingen, het orale comfort negatief beïnvloeden. Immers, veranderingen vereisen weer aanpassing van de patiënt aan een nieuwe mondsituatie.

De conclusie is dat een VTB (bestaande uit 3-5 OE) in voldoende oraal comfort kan voorzien. Vrij-eindigende partiële prothesen (in de onderkaak) leveren geen positieve bijdrage aan het comfort. Integendeel, personen met een dergelijke voorziening zeiden vaker te bruxeren. Bovendien vereisen deze prothesen veel na-behandelingen, hetgeen bleek uit de retrospectieve gegevens van de behandelkaarten van 23 personen. Deze kaarten beschreven een periode van 6.9 jaar. Een aanzienlijk deel van de personen (5 van de 23) besloot gedurende deze periode de prothese niet meer te dragen.

In hoofdstuk 6 is een verklaring gegeven voor het feit, dat slechts 10% van de personen met een VTB klaagde over de kauwfunctie. De kauwfunctie wordt hier gedefiniëerd als de zelf ervaren, subjectieve kauwcapaciteit, dus in termen van kauwcomfort. In een literatuurstudie wordt bevestigd, dat de gevonden uitkomst in overeenstemming is met andere studies. Deze geven in feite aan, dat de kauwfunctie als voldoende wordt ervaren, zolang 20 of meer gebitselementen aanwezig zijn, die dan goed verdeeld en gepositioneerd moeten zijn over de tandbogen. Dit is kennelijk in een VTB het geval. Een VTB leidt ook niet tot een verschuiving in de voedselkeuze. Economische en sociaal-psychologische factoren worden in de westerse wereld belangrijker geacht voor de voedselkeuze dan tandheelkundige.

Het kauwvermogen wordt gedefinieerd als de objectief vast te stellen capaciteit van de dentitie om voedselpartikels in grootte te reduceren.

De afwezigheid van molaren in een VTB lijkt het objectief vast te stellen kauwvermogen meer te beïnvloeden dan de subjectief ervaren kauwfunctie. In de literatuur kon een relatie tussen enerzijds een slecht kauwvermogen en anderzijds maagklachten, voedingsdeficiënties of een slechtere algemene gezondheid ten gevolge hiervan, niet worden aangetoond.

Hoofdstuk 7 gaat over de parodontale steun van de gebitselementen in VTB's. Hiervoor werden de mobiliteit van de gebitselementen en de (relatieve) alveolaire bothoogte, gemeten op röntgenfoto's, als parameters gebruikt. De resultaten geven aan, dat VTB 's, met of zonder vrij-eindigende PP, meer mobiele elementen hebben en lagere bothoogtescores. Eindstandige premolaren hebben een gering verhoogd risico in dit opzicht vergeleken met niet-eindstandige premolaren. Dat geldt eveneens voor de pijlerelementen voor een vrij-eindigend frame. Gevallen van verlies van gebitselementen in de VTB groep en de VTB + PP groep geven aan, dat de combinatie van verhoogde occlusale belasting, te zamen met een reeds bestaande slechte parodontale situatie, een verhoogd risico vormt voor verdere parodontale afbraak.
Misleidende variabelen, zoals het tandheelkundige verleden van de patiënt, dat uiteindelijk heeft geleid tot een VTB, maken longitudinale gegevens noodzakelijk om een beter zicht te krijgen op het effect van een VTB op het parodontium.

Hoofdstuk 8 geeft de bevindingen met betrekking tot de migratie van de gebitselementen en de parodontale steun aan het begin van de studie, en vervolgens bij een 3-jaars en een 6-jaars evaluatie.

In de VTB en de VTB + PP groep is een trend naar toenemende occlusale contacten in het front gedurende de evaluatie-periode. De verticale overbeet daarentegen blijft stabiel. Voor wat betreft de diasteemvorming werd geen tijd-effect waargenomen, met uitzondering van de VTB + PP groep. Dit wijst erop dat in de VTB groep na aanvankelijke, geringe migraties, een nieuw evenwicht ontstaat, dat leidt tot een stabiele occlusie.

Voor wat betreft de steun van het alveolaire bot aan de gebitselementen is de situatie gecompliceerder. Enerzijds laat de uitval van enkele personen gedurende de evaluatie-periode ten gevolge van het verlies van één of meer gebitselementen, zien, dat een VTB met bestaande, ernstige parodontale afwijkingen, verdere parodontale afbraak tot gevolg kan hebben. Anderzijds is een significant tijd-effect bij een vergelijking van de drie patiëntengroepen, die zou duiden op een progressieve vermindering van de bothoogte-scores alleen gevonden voor de elementen 14 en 25, en wel voornamelijk in de VTB + PP groep. Dit duidt erop dat de gevonden lagere bothoogte-scores in de VTB en de VTB + PP groep de weerslag zijn van een tandheelkundig verleden, dat tot de VTB heeft geleid.

Op grond van de resultaten wordt geconcludeerd dat VTB's met 3-5 OE, met of zonder vrij-eindigende partiële prothese, voorzien in voldoende occlusale stabiliteit gedurende een langere periode.

In hoofdstuk 9 worden de bevindingen weergegeven met betrekking tot symptomen van CMD en het ervaren orale comfort, zowel aan het begin van de studie als bij de 3-jaars en de 6-jaars evaluatie.

De resultaten geven aan, dat VTB's, bestaande uit 3-5 OE, voldoende oraal comfort bieden en dat de afwezigheid van molaren niet gezien kan worden als een risico-factor voor CMD. Vrij-eindigende partiële prothesen (in de onderkaak) verbeteren de gebitsfunc-ties niet. Deze voorziening blijkt veel nabehandeling te vereisen.

De methodologie en de voornaamste resultaten worden bediscussiëerd in hoofdstuk 10. Onderzoek dat op verschillende plaatsen wordt gedaan, zogenaamd "multi-centered" onderzoek, wordt aanbevolen voor klinische studies als de onderhavige.

De resultaten van dit onderzoek ondersteunen het VTB-concept wat betreft de aanname van optimale en suboptimale functionele niveau's (tabel 1-2). Dit betekent dat bij risicogroepen de behandeldoelen beperkt kunnen worden, hetgeen belangrijke voordelen heeft. De orale functionele behoeften veranderen met het ouder worden en kunnen met minder dan 14 occlusale eenheden worden bevredigd, hetgeen een verandering in behandelstrategie inhoudt. Beperkte behandeldoelen bij risicogroepen kunnen, naast een probleemgerichte aanpak, worden gerealiseerd met het verkorte tandboog concept. Tot

welke leeftijd molaar-afsteuning noodzakelijk is, verdient nader onderzoek. Ook voor het kwantificeren van het kosten-baten aspect bij beperkte behandeldoelen is nader onderzoek nodig.

Curriculum Vitae

De auteur van dit proefschrift werd in 1947 te Poortugaal (Z.H.) geboren. Na het behalen van het 3-jarig H.B.S. getuigschrift (1963) was hij enige jaren administratief werkzaam bij de gemeente Rotterdam. Na het vervullen van de militaire dienstplicht (1967-1968) behaalde hij aan de Chr. H.B.S. "Blaise Pascal" te Spijkenisse het H.B.S.-B diploma (1970). Hierna volgde de studie tandheelkunde aan de Katholieke Universiteit te Nijmegen, waar hij in 1976 het tandartsexamen aflegde. Sindsdien is hij werkzaam aan het Instituut voor Occlusie-opbouw (hoofd Prof. dr. A.F. Käyser), sinds 1989 deel uitmakend van de Vakgroep Orale Functieleer (hoofd Prof. dr. A.F. Käyser, sinds 01-06-1993 Prof. dr. W. Kalk).

STELLINGEN
bij het proefschrift

A 6-YEAR FOLLOW-UP STUDY OF THE ORAL FUNCTION IN SHORTENED DENTAL ARCHES

D.J. Witter, 27 september 1993

1. Veel tandheelkundig onderzoek naar de gebitsfuncties is nauwelijks te interpreteren omdat slechts het aantal gebitselementen wordt vermeld en niet de locatie ervan.

2. Ook met een verkorte tandboog kun je je tanden laten zien.

3. Een verkorte tandboog is een gebit zonder einde.

4. Voorbijgaan aan de subjectieve behandelbehoefte door de tandheelkundige professie kan gemakkelijk leiden tot overtreatment.

5. Met een verkorte tandboog eindigt men hoe men als kind begon, namelijk met 12 tanden en 8 kiezen.

6. Parapulpaire pinnen zijn net als tentharingen: ze zijn moeilijk aan te brengen en ze voldoen, zolang ze maar weinig te houden hebben.

7. In de bestaande endodontische leerboeken wordt ten onrechte verzuimd de volledige kroonpreparatie bij de devitalisatiemiddelen te vermelden.

8. Het primaat van de opvoeding berust bij de ouders of verzorgers en niet bij de school of andere instanties.

9. Indien het invoeren van moderne medische verzorging in primitieve (zogenaamde 3e wereld) landen niet gepaard gaat met het invoeren van een bevolkingspolitiek, kan men beter de traditionele medicijnman handhaven.

10. Omdat betaald voetbal en alles wat daarmee samenhangt wel ongeveer als maatschappelijke uitwas dient te worden beschouwd, moet door betrokken overheden een ontmoedigingsbeleid worden nagestreefd in plaats van een aanmoedigingsbeleid middels (verkapte) subsidies.

11. Er is dringend onderzoek nodig naar de maximale inhoud van motoren van bromfietsen om deze weer "rijwiel met hulpmotor" te doen zijn (gezien de technische ontwikkelingen, maar vooral gezien het weggedrag van deze categorie blijde rijders).

12. Op alle openbare plaatsen moet een hond zijn aangelijnd aan de bezitter, of andersom.

Abstract

A 6-year follow-up study of the oral function in shortened dental arches

By Dick J. Witter, Department of Oral Function and Prosthetic Dentistry, University of Nijmegen, The Netherlands.

The objective of this study was to investigate the long-term relation between shortened dental arches (SDA) and oral function. The motive for this study was to investigate the question as to whether SDA can be an acceptable dental treatment option in high risk groups.

A SDA is defined as a reduced dental arch consisting of a complete anterior region and between three to five occlusal units posteriorly. Three groups of subjects were selected from the patient population of the dental school of the University of Nijmegen and followed for six years: a SDA group (n=74), a SDA group provided with free-end removable partial dentures in the lower jaw (n=25) and a control group with complete dental arches.

In the dental literature and prosthetic textbooks a SDA condition is associated with some major problems.

SDA were supposed to threaten the occlusal stability, characterized by an increased overbite and interdental spacing of the upper anterior teeth caused by decrease of the vertical dimension due to migration of the premolars, and finally leading to an anterior bite collapse. Based on the findings of this study, when observing the variables: occlusal contact, overbite and interdental spacing, it is concluded that minor changes do occur, but that a new occlusal equilibrium remains stable. Effects in terms of collapse of the bite do not take place.

As a result of occlusal overloading in SDA, as fewer teeth remain to absorb the occlusal forces, the remaining dentition should have a greater risk for progressive periodontal breakdown. When considering the alveolar bone support it is concluded that a SDA bears no risk as the alveolar bone support in the SDA group tends to decrease in the same degree as in the control group with complete dental arches. It is discussed that progressive periodontal breakdown in some subjects with SDA is not a SDA effect, but the result of the dental history of these subjects, leading to a SDA with poor periodontal prognosis.

SDA were supposed to provoke mandibulair dysfunction. The results of this study, analysing objective and subjective signs and symptoms, indicate that a SDA is not a risk factor for dysfunction. Therefore it is necessary to specify "posterior support" for the Temporomandibulair Joint into molar and premolar support. Obviously changes in the stomatognathic system as a result of SDA are within the adaptive capacity of the structures of the joint.

SDA were also supposed to impair oral comfort. When considering the subjective signs and symptoms of mandibular dysfunction, aesthetics and masticatory ability, the results of this study indicate that SDA do provide sufficient oral comfort for a long-term period.

Traditionally SDA were extended with free-end removable partial dentures (RPD's). This study shows that free-end RPD (in the lower jaw) do not improve oral function. The subjects report more frequently bruxism, possibly provoked by occlusal interferences created by the clasps of the RPD. Free-end RPD 's are a frequent cause for re-treatment and some subjects decided to wear this appliance no longer. Insertion of a RPD in a SDA condition is often an example of overtreatment.

The final conclusion is that SDA do provide sufficient oral function during a long-term period. In high-risk groups, especially starting from the middle-aged, the SDA-concept can be an acceptable treatment option, aiming at limited treatment goals.