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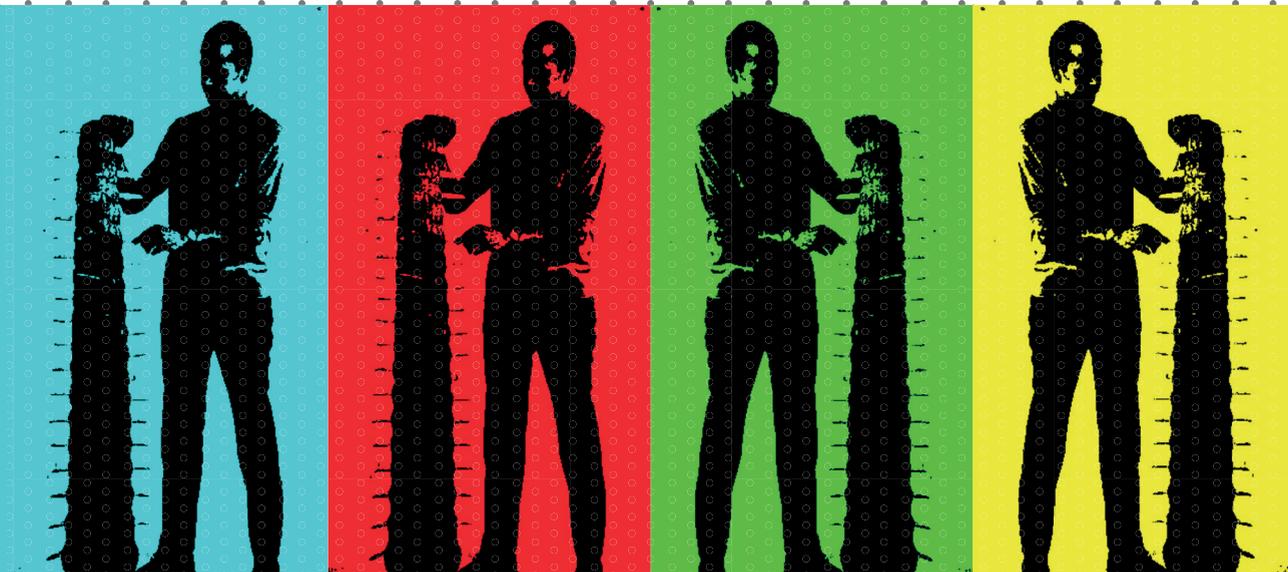
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THE SHORTENED DENTAL ARCH CONCEPT RE-EVALUATED

Anneloes Gerritsen



The shortened dental arch concept re-evaluated

Long-term clinical outcomes, oral health-related quality of life, and
qualitative evaluation of patient attitudes

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Cover in pop-art style referring to the time the shortened arch concept was firstly described by prof. dr. Arnd Käyser (1932-1998), on cover photo holding 'the saw' of a sawfish.

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The shortened dental arch concept re-evaluated

Long-term clinical outcomes, oral health-related quality of life, and qualitative evaluation
of patient attitudes

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Chapter 1

General introduction

Based on: Gerritsen AE, Witter DJ, Creugers NHJ. Is het concept van de verkorte tandboog nog van deze tijd? Het tandheelkundig jaar 2016. Houten, Bohn Stafleu van Loghum; 2015.p.191-202.

Background

Shortened dental arches are dentitions with a complete anterior region and a reduction of occluding pairs of teeth starting posteriorly. In moderate shortened dental arches, all or most molar occluding pairs are absent, with all or most premolars present. When people with moderate shortened dental arches are asked about the functionality of their dentition, they generally respond that they are able to function adequately and perceive little or no specific complaints. Consequently, patients often accept this condition without replacement of their lost posterior teeth [1]. Based on these clinical observations, Käyser introduced the shortened dental arch concept in the seventies of the last century [2].

Although not denoted explicitly at that time, the concept entails an 'active' and a 'passive' variant. In the active variant, it is considered to extract and not to restore molars with a doubtful prognosis or requiring complex interventions and disproportionate investments for surviving. Simultaneously, all necessary efforts should be made to preserve 'the strategic part' of the dentition, comprising the anterior and premolar teeth. In this way, the concept aims to preserve healthy and functional, albeit reduced dentitions. The passive variant applies to existing shortened dental arches. In contrast to generally accepted clinical practice at that time, applying this variant shortened dental arches are not extended to avoid distal-extension removable dental prostheses.

The concept of the shortened dental arch was prompted by a number of considerations. The first consideration was of a biological nature: new occlusal concepts were developed, changing from a morphological and mechanical approach in which ideally complete dental arches were pursued toward a biological approach. In the latter approach the presence of adaptation mechanisms within the orofacial and occlusal system was recognized. Consequently, variability in form and function of a dentition was no longer considered as conflicting with a healthy orofacial and occlusal system. Following this reasoning, the presence of a complete posterior support zone by the presence of the premolars and all molars was no longer considered to be strictly necessary. A second consideration was that most people with absent molars generally experience an acceptable level of oral functions [3]. The third consideration was that molars were often the first teeth to deteriorate [4-7]. Treatment of these teeth in general was extensive and often did not provide sustainable satisfactory results. The fourth consideration was that that in the 1970's extension of shortened dental arches was actually only possible with distal-extension removable dental prostheses. For many owners, this type of denture is rather a cause than a solution for their possible functional

problems [1]. However, since the seventies of the last century when Käyser (1989) introduced the shortened dental arch concept, (oral) health care underwent drastic changes and developments such as the successful implementation of preventive measures and new treatment methods including oral implants [2]. Also, higher expectations of more-demanding patients, together with an increased economic prosperity induced changes in attitudes toward dental treatment. These changes might have influenced the thinking about the shortened dental arch concept and its application in daily practice. If present-day patients consider a shortened dental arch as an 'inferior' situation that could possibly be avoided, then the question arises whether the concept is still viable today. The extent to which the shortened dental arch concept and the underlying considerations still apply today will be elaborated further in this introduction chapter.

Shortened dental arches and the orofacial and occlusal system

Slightly shortened dental arches in which - unilateral or bilateral - only the second and third molars are absent (i.e. 6 to 8 posterior occlusal pairs present) have hardly been subject of investigation, because impairment of oral function in this condition is hardly identifiable or measurable and unlikely to be clinically relevant. Moderate shortened dental arches are dentitions with a complete anterior region and a further reduction of teeth starting posteriorly, and comprise of 3 to 5 posterior occlusal pairs. The majority of studies found in the dental literature on shortened dental arches are reporting on moderate shortened dental arches. Relatively few studies report on so-called extreme shortened dental arches (complete anterior region and 0 to 2 posterior occluding pairs).

Biological aspects

As already mentioned, the presence of a complete dorsal support zone including all molars is considered to be not strictly necessary for 'normal' oral functions. These oral functions include biological functions, in particular the provision of stability to the temporomandibular joints (mandibular stability) and to the remaining teeth (occlusal stability). With regard to mandibular stability: with the reduction of posterior occlusal support minor changes can be seen in the position of the condyles in the temporomandibular joints, but these changes can also be regarded as a result of adaptation [8]. The dental literature provides evidence that people with shortened dental arches do not report more frequent or severe symptoms of temporomandibular

dysfunction than people with complete dental arches [3]. With regard to occlusal stability it is known that after tooth loss leading to a moderate shortened dental arch, slight migration of teeth occurs in the majority of individuals, but after some time occlusal stability develops as a result of a new occlusal equilibrium [9]. The effects of a shortened dental arch on the periodontal condition of the dentition are not clear. The observed reduction of the periodontal attachment is considered not a direct effect of a shortened dental arch condition due to increased occlusal load per tooth, but the result of previous conditions - such as less effective oral (self-)care - that have led to both the arch 'shortening' as well as to deterioration of the periodontal condition of the teeth [9, 10]. Also, risk for clinical relevant increase of occlusal tooth wear by increased occlusal load per tooth is proven to be limited [9, 11, 12].

Functional aspects

Beside the above-mentioned biological functions, satisfactory appearance and masticatory function belong to the most important functions of the dentition. Curiously, knowledge about the aesthetic aspects of shortened dental arches is very limited. With active query including specific questions, 24% of a cohort of adults in Tanzania raised aesthetic complaints on the absence of a maxillary first premolar, 11% on the absence of a maxillary second premolar, and 1% on the absence of a maxillary molar [13]. The objectively measured masticatory performance of people with a shortened dental arch is - due to the reduced occlusal surface - considerably lower than that of people with a complete dentition. However, this finding seems to be partly due to the use of tough artificial test materials in mastication experiments [14-17]. Regarding the subjective (self-reported) masticatory function, people with moderate shortened dental arches reported little or no complaints about their chewing function with soft foods, but regularly minor problems with hard foods [18, 19].

Sustainability and oral health-related quality of life

Tooth loss is usually the ultimate result of caries or periodontal disease. Molars that have been lost in people with a shortened dental arch are no exception. After the loss of molars, the susceptibility of the remaining teeth to these microbiological diseases does not disappear. Consequently, it should be realized that people with a shortened dental arch might constitute a permanent risk group for dental diseases and therefore have an increased risk for further deterioration and tooth loss. This assumed permanent high risk

might have a negative impact on the sustainability of a shortened dental arch. Based on a randomised controlled clinical trial Walter et al (2013) reported tooth loss in 25% of patients with extensively rehabilitated moderate shortened dental arches after a 5 year follow-up [20]. A prospective case-control cohort study reported that in a 5 year period in 99 subjects with moderate shortened dental arches with and without distal-extension removable dental prostheses only 14 teeth were lost [21], which is considerably fewer than in the study of Walter et al. [20]. However, to date evidence related to this matter is based on relative short-term studies.

Besides the aforementioned clinical aspects, oral health-related quality of life (OHRQoL) as an outcome measure is an important indicator for oral health. OHRQoL is a complex concept, which refers to the relationship between oral health and quality of life. It has been reported that tooth loss generally leads to impaired OHRQoL [22-24]. No data are available pointing at a certain threshold on how many teeth are exactly needed for acceptable OHRQoL. Moreover, it is assumed that the impact of tooth loss might be related to the cultural background of an individual. Studies on specific quality of life aspects of subjects with shortened dental arches are available from different countries, with a relative large contribution from Japan. In general, studies amongst Japanese people report (some) benefit from extending moderate shortened dental arches with fixed or removable dental prostheses [25]. A randomised clinical trial from Ireland showed better OHRQoL outcomes for patients treated according to the shortened dental arch concept than for those provided with removable dental prostheses to restore to complete dental arches [26]. Armelini et al. (2008) reported from a two-centre clinical study in the USA that distal-extension removable dental prostheses improved OHRQoL only if they included the replacement of missing anterior teeth [27]. Data from a randomised shortened dental arch study in Germany indicate no significant differences between groups of patients that were treated following the shortened dental arch concept and those treated with distal-extension removable dental prostheses [28]. It is worthwhile to mention that treatment approaches in different countries may differ considerably, e.g. because of different economic situations and reimbursement systems. These differences may confound the outcomes of the OHRQoL studies and explain differences in those outcomes. OHRQoL data for people with long-term shortened dental arches from the Netherlands are lacking.

Socio-dental developments

At the time the concept of the shortened dental arch was introduced, the oral health condition of the Dutch population was generally poor [29]. The concept was therefore considered a viable treatment strategy for patients with heavily deteriorated molars. The intention of this treatment strategy was – especially in case of limited resources - to preserve the anterior teeth and premolars without complex and costly restorative treatment of molars, consequently reducing the burden of maintenance and plaque control in the posterior region. Since the introduction of the shortened dental arch concept, clinical dentistry changed substantially in many areas. As a result of the effective application of fluoride and other preventive measures, oral health of the Dutch population has improved dramatically [29]. Additionally, advances in the field of sub-disciplines such as periodontology, endodontology and restorative and prosthetic dentistry contributed to more effective and predictable treatments and thus to more sustainable (reduced) dentitions. Today, it therefore seems a more prevailing strategy to put more emphasis on the preservation of molar support. However, such a preservation might be not achievable nor affordable for dentate elderly, especially for those with imminent frailty.

Not only changes in oral health and dentistry took place after the first (international) publication on the shortened dental arch concept in the early 1980s [30] but also fundamental societal transformations. Probably, this also has influenced patients' attitude toward the acceptance of absent posterior teeth. Whereas in the past tooth loss was often accepted as a part of a natural ageing process, nowadays patients expect to remain their teeth for life. Contemporary patients may have high expectations regarding (oral) health care, are assertive and have access to abundant information about disease and treatment options via media such as the internet. Consequently, if tooth loss occurs they are more demanding regarding tooth replacement. Therefore, it can be assumed that, although a moderate shortened dental arch can fulfil the requirements of a functional dentition, an increasing number of patients inquire about the possibilities of replacement of their absent posterior teeth.

Treatment options for posterior tooth replacement

If loss of molar support is inevitable, the patient has to evaluate the functionality of his remaining dentition and to consider – as part of a shared decision-making process -

whether replacement is desired. The replacement of absent molars by distal-extension removable dental prostheses – at the time of the introduction of the concept practically the only treatment option - is more or less irrational, because this type of prostheses cannot contribute to durable occlusal stability as a result of progressing atrophy of the residual alveolar ridge. Moreover, distal-extension removable dental prostheses do not provide significant improvement of masticatory function [31] nor leads to a better nutritional status compared to a shortened dental arch condition [32, 33]. Time and again, research has provided evidence that (distal-extension) removable dental prostheses pose a potential risk for deterioration of the remaining teeth [34], while they are experienced uncomfortable to such a degree that they are often not used [35]. It is therefore not surprising that these dentures do not improve OHRQoL of people with shortened dental arches [26, 28].

Treatment demand is determined by patient-related factors such as individual preferences, culture and age and can change with the availability of new treatment options and resources [36]. Unlike 40 years ago, present-day dentists are more reluctant to extend shortened dental arches with removable dental prostheses. In contrast, application of fixed distal-extension dental prostheses and implant-supported prostheses has increased. For fixed conventional dental prostheses (both single- and multi-unit) systematic reviews reported a 10-year survival of approximately 90% [37, 38]. For fixed distal-extension dental prostheses the 10-year survival was calculated to be approximately 80% and for (distal-extension) implant-supported fixed prostheses again 90% [39, 40]. Combined tooth- and implant-supported prostheses have a slightly higher risk with a 10-year survival of approximately 80% [37]. Resin-bonded dental prostheses have a significantly lower 10-year survival of 65%; for distal-extension resin-bonded dental prostheses in mandibular shortened dental arches the 5-year survival was estimated to be approximately 70% [41]. Increased treatment demand arises from higher expectations towards (dental) care in today's generations compared to former generations [42]. People have become more assertive, are better informed, and expect that they can participate actively in shared decision-making processes with regards to treatment options [43]. Considering today's treatment options, if people with shortened dental arches perceive functional impairment it is not common to advocate distal-extension removable prostheses, but to put forward fixed (implant-supported) prostheses. Due to the increased prosperity of Western populations in recent decades,

fixed dental prostheses are probably better affordable for more people and therefore provide a feasible solution for improvement of functionally impaired reduced dentitions.

Conclusion

There are no valid arguments for stating that complete dental arches are necessary for a healthy orofacial or occlusal system. From a biological and functional point of view, moderate shortened dental arches provide, for the majority of people, acceptable conditions. For these reasons applying the concept of the shortened dental arch is worth considering when treating (reduced) dentitions. However, the sustainability of shortened dental arches and whether the concept – given the socio-demographic changes and today's options for posterior tooth replacement - continues to be a relevant treatment strategy needs further investigation.

Objectives of the studies in this thesis

The general objective of this study is to investigate to what extent shortened dental arches provide long-term sustainability and to explore the impact of absent teeth on OHRQoL, and perceptions and attitudes of people towards having a shortened dental arch condition.

The specific objectives addressed in this thesis are:

1. To systematically review the literature in order to analyse the relationship between the number (threshold) and location of missing teeth and OHRQoL.
2. To evaluate the clinical course of a cohort of subjects with shortened dental arches by analysing follow-up data on the basis of information from patient records.
3. To analyse the sustainability of shortened dental arches by considering two clinical endpoints: (1) time to the first restorative intervention of teeth, and (2) time to tooth loss.
4. To assess and analyse the OHRQoL of people with a shortened dental arch condition using the OHRQoL of people having a complete dental arch as a reference.
5. To explore, in a qualitative study, perceptions and attitudes of people with a shortened dental arch towards absent posterior teeth and tooth replacement treatment.

Outline of the thesis

Chapter 1 provides a general introduction on the shortened dent arch concept.

Chapter 2 presents a systematic review and meta-analysis assessing the relationship between number and location of absent teeth and OHRQoL. It is expected that tooth loss is associated with impairment of OHRQoL. It is hypothesized that location and distribution of missing teeth play an important role in this respect.

Chapter 3 describes the clinical course of shortened dental arches in a cohort of subjects on the basis of information from records of patients. Subjects with shortened dental arches are compared with subjects with shortened dental arches that were extended with distal-extension removable dental prostheses and subjects with complete dental arches. Evaluation variables are (1) changes in the dental arch condition, (2) management of tooth loss and (3) restorative interventions provided during the follow-up period.

A study on the sustainability of shortened dental arches is described in **Chapter 4**. This investigation includes the same cohorts of subjects with shortened dental arches with and subjects without distal-extension removable dental prostheses, and subjects with complete dental arches. Evaluation criteria are (1) time to the first restorative intervention of teeth, and (2) time to tooth loss. It is expected that subjects with shortened dental arches have higher hazard probabilities for 'first restorative intervention' and 'tooth loss' compared to hazard probabilities of subjects with complete dental arches and lower compared to those of subjects with shortened dental arch with distal-extension removable dental prosthesis.

The aim of the study presented in **Chapter 5** was to assess and analyse the OHRQoL of people with a shortened dental arch condition using the OHRQoL scores of people having complete dental arches as a reference. Apart from statistical differences, the minimal important difference (MID) is used as a benchmark to assess what is clinically significant in terms of patient-based outcomes.

The qualitative study in **Chapter 6** explores perceptions and attitudes of people with a shortened dental arch towards absent posterior teeth and tooth replacement treatment with the aim to help dentists to better understand and inform patients presenting with this condition.

Chapter 7 presents an integral discussion on the findings of the studies described in the previous chapters. Some recommendations for further research in this field are also provided.

The studies in this thesis are summarized in **Chapter 8**, respectively in English and Dutch.

References

1. Witter DJ, van Palenstein Helderma WH, Creugers NHJ, Käyser AF. The shortened dental arch concept and its implications for oral health care. *Community Dent Oral Epidemiol.* 1999;27:249-58.
2. Käyser AF. Shortened dental arch: a therapeutic concept in reduced dentitions and certain high-risk groups. *Int J Periodontics Restorative Dent.* 1989;9:426-49.
3. Gotfredsen K, Walls AW. What dentition assures oral function? *Clin Oral Implants Res.* 2007;18 Suppl 3:34-45.
4. Axelsson P, Lindhe J. The effect of a plaque control program on gingivitis and dental caries in schoolchildren. *J Dent Res.* 1977;56 Spec No:C142-8.
5. Bahrami G, Vaeth M, Kirkevang LL, Wenzel A, Isidor F. Risk factors for tooth loss in an adult population: a radiographic study. *J Clin Periodontol.* 2008;35:1059-65.
6. Fure S. Ten-year incidence of tooth loss and dental caries in elderly Swedish individuals. *Caries Res.* 2003;37:462-9.
7. Paulander J, Axelsson P, Lindhe J, Wennström J. Intra-oral pattern of tooth and periodontal bone loss between the age of 50 and 60 years. A longitudinal prospective study. *Acta Odontol Scand.* 2004;62:214-22.
8. Seedorf H, Seetzen F, Scholz A, Sadat-Khonsari MR, Kirsch I, Jude HD. Impact of posterior occlusal support on the condylar position. *J Oral Rehabil.* 2004;31:759-63.
9. Witter DJ, Creugers NHJ, Kreulen CM, de Haan AF. Occlusal stability in shortened dental arches. *J Dent Res.* 2001;80:432-6.
10. Walter MH, Marré B, Vach K, Strub J, Mundt T, Stark H, et al. Management of shortened dental arches and periodontal health: 5-year results of a randomised trial. *J Oral Rehabil.* 2014;41:515-22.
11. Van't Spijker A, Kreulen CM, Bronkhorst EM, Creugers NHJ. Occlusal wear and occlusal condition in a convenience sample of young adults. *J Dent.* 2015;43:72-7.
12. Zhang Q, Witter DJ, Bronkhorst EM, Bartlett DW, Creugers NHJ. Occlusal tooth wear in Chinese adults with shortened dental arches. *J Oral Rehabil.* 2014;41:101-7.
13. Gerritsen AE, Sarita P, Witter DJ, Kreulen CM, Mulder J, Creugers NHJ. Esthetic perception of missing teeth among a group of Tanzanian adults. *Int J Prosthodont.* 2008;21:169-73.
14. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, Van THMA, Witter DJ, Kalk W, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res.* 2000;79:1519-24.
15. Aras K, Hasanreisoglu U, Shinogaya T. Masticatory performance, maximum occlusal force, and occlusal contact area in patients with bilaterally missing molars and distal extension removable partial dentures. *Int J Prosthodont.* 2009;22:204-9.
16. Kreulen CM, Witter DJ, Tekamp FA, Slagter AP, Creugers NHJ. Swallowing threshold parameters of subjects with shortened dental arches. *J Dent.* 2012;40:639-43.
17. Witter DJ, Woda A, Bronkhorst EM, Creugers NHJ. Clinical interpretation of a masticatory normative indicator analysis of masticatory function in subjects with different occlusal and prosthodontic status. *J Dent.* 2013;41:443-8.
18. Sarita PT, Witter DJ, Kreulen CM, Van't Hof MA, Creugers NHJ. Chewing ability of subjects with shortened dental arches. *Community Dent Oral Epidemiol.* 2003;31:328-34.
19. Zhang Q, Witter DJ, Bronkhorst EM, Creugers NHJ. Chewing ability in an urban and rural population over 40 years in Shandong Province, China. *Clin Oral Investig.* 2013;17:1425-35.
20. Walter MH, Hannak W, Kern M, Mundt T, Gernet W, Weber A, et al. The randomized shortened dental arch study: tooth loss over five years. *Clin Oral Investig.* 2013;17:877-86.
21. Witter DJ, De Haan AF, Käyser AF, Van Rossum GM. Shortened dental arches and periodontal support. *J Oral Rehabil.* 1991;18:203-12.
22. Ide R, Yamamoto R, Mizoue T. The Japanese version of the Oral Health Impact Profile (OHIP)--validation among young and middle-aged adults. *Community Dent Health.* 2006;23:158-63.
23. Lahti S, Suominen-Taipale L, Hausen H. Oral health impacts among adults in Finland: competing effects of age, number of teeth, and removable dentures. *Eur J Oral Sci.* 2008;116:260-6.

- 24.** Steele JG, Sanders AE, Slade GD, Allen PF, Lahti S, Nuttall N, et al. How do age and tooth loss affect oral health impacts and quality of life? A study comparing two national samples. *Community Dent Oral Epidemiol.* 2004;32:107-14.
- 25.** Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont.* 2008;21:72-4.
- 26.** McKenna G, Allen PF, O'Mahony D, Cronin M, DaMata C, Woods N. The impact of rehabilitation using removable partial dentures and functionally orientated treatment on oral health-related quality of life: a randomised controlled clinical trial. *J Dent.* 2015;43:66-71.
- 27.** Armellini DB, Heydecke G, Witter DJ, Creugers NHJ. Effect of removable partial dentures on oral health-related quality of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont.* 2008;21:524-30.
- 28.** Wolfart S, Müller F, Gerss J, Heydecke G, Marré B, Boning K, et al. The randomized shortened dental arch study: oral health-related quality of life. *Clin Oral Investig.* 2014;18:525-33.
- 29.** van Loveren C, Eijkman MA. Preventie op koers? Investeren bijft noodzaak. *Ned Tijdschr Tandheelkd.* 2003;110:493-9.
- 30.** Käyser AF. Shortened dental arches and oral function. *J Oral Rehabil.* 1981;8:457-62.
- 31.** Liang S, Zhang Q, Witter DJ, Wang Y, Creugers NHJ. Effects of removable dental prostheses on masticatory performance of subjects with shortened dental arches: A systematic review. *J Dent.* 2015;43:1185-94.
- 32.** McKenna G, Allen PF, Flynn A, O'Mahony D, DaMata C, Cronin M, et al. Impact of tooth replacement strategies on the nutritional status of partially-dentate elders. *Gerodontology.* 2012;29:e883-90.
- 33.** Moynihan PJ, Butler TJ, Thomason JM, Jepson NJ. Nutrient intake in partially dentate patients: the effect of prosthetic rehabilitation. *J Dent.* 2000;28:557-63.
- 34.** Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J.* 2001;191:140-4.
- 35.** Smith PA, Entwistle VA, Nuttall N. Patients' experiences with partial dentures: a qualitative study. *Gerodontology.* 2005;22:187-92.
- 36.** Narby B, Kronström M, Söderfeldt B, Palmqvist S. Prosthodontics and the patient: what is oral rehabilitation need? Conceptual analysis of need and demand for prosthodontic treatment. Part 1: a conceptual analysis. *Int J Prosthodont.* 2005;18:75-9.
- 37.** Pjetursson BE, Lang NP. Prosthetic treatment planning on the basis of scientific evidence. *J Oral Rehabil.* 2008;35 Suppl 1:72-9.
- 38.** Goodacre CJ, Naylor WP. Single implant and crown versus fixed partial denture: A cost-benefit, patient-centred analysis. *Eur J Oral Implantol.* 2016;9 Suppl 1:S59-68.
- 39.** Aglietta M, Siciliano VI, Zwahlen M, Bragger U, Pjetursson BE, Lang NP, et al. A systematic review of the survival and complication rates of implant supported fixed dental prostheses with cantilever extensions after an observation period of at least 5 years. *Clin Oral Implants Res.* 2009;20:441-51.
- 40.** Zurdo J, Romao C, Wennström JL. Survival and complication rates of implant-supported fixed partial dentures with cantilevers: a systematic review. *Clin Oral Implants Res.* 2009;20 Suppl 4:59-66.
- 41.** Thomason JM, Moynihan PJ, Steen N, Jepson NJ. Time to survival for the restoration of the shortened lower dental arch. *J Dent Res.* 2007;86:646-50.
- 42.** Cronin M, Meaney S, Jepson NJ, Allen PF. A qualitative study of trends in patient preferences for the management of the partially dentate state. *Gerodontology.* 2009;26:137-42.
- 43.** Watson R. European countries face similar problems of demographic ageing and higher patient expectations. *BMJ.* 2001;323:1388.

Chapter 2

Tooth loss and oral health-related quality of life: a systematic review and meta-analysis

Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NHJ. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health and Quality of Life Outcomes*. 2010;8:126.

Abstract

Aim

To systematically review the literature and to analyse the relationship between the number and location of missing teeth and oral health-related quality of life (OHRQoL). It was hypothesized that tooth loss is associated with an impairment of OHRQoL. Secondly, it was hypothesized that location and distribution of remaining teeth play an important role in this.

Methods

Relevant databases were searched for papers in English, published from 1990 to July 2009 following a broad search strategy. Relevant papers were selected by two independent readers using predefined exclusion criteria, firstly on the basis of abstracts, secondly by assessing full-text papers. Selected studies were grouped on the basis of OHRQoL instruments used and assessed for feasibility for quantitative synthesis. Comparable outcomes were subjected to meta-analysis; remaining outcomes were subjected to a qualitative synthesis only.

Results

From a total of 924 references, 35 were eligible for synthesis (inter-reader agreement abstracts $\kappa = 0.84 \pm 0.03$; full-texts: $\kappa = 0.68 \pm 0.06$). Meta-analysis was feasible for 10 studies reporting on 13 different samples, resulting in 6 separate analyses. All studies showed that tooth loss is associated with unfavourable OHRQoL scores, independent of study location and OHRQoL instrument used. Qualitative synthesis showed that all 9 studies investigating a possible relationship between number of occluding pairs of teeth present and OHRQoL reported significant positive correlations. Five studies presented separate data regarding OHRQoL and location of tooth loss (anterior tooth loss vs. posterior tooth loss). Four of these reported highest impact for anterior tooth loss; one study indicated a similar impact for both locations of tooth loss.

Conclusions

This study provides fairly strong evidence that tooth loss is associated with impairment of OHRQoL and location and distribution of tooth loss affect the severity of impairment. This association seems to be independent from the OHRQoL instrument used and context of the included samples.

Background

It is increasingly recognized that the impact on quality of life (QoL) of disease and treatment of disease and its consequences should be taken into account when assessing health status and evaluating treatment outcomes. Clinical indicators only are not sufficient to describe health status and it has been reported that people with chronic disabling disorders can perceive their quality of life as better than healthy individuals, i.e., poor health or presence of disease does not inevitably mean poor quality of life [1, 2]. Adaptive capacity and personal characteristics appear to influence patient's response to chronic disease. This can result in reports which seem counterintuitive, for example, the finding in a large German survey that having fewer than 9 teeth had more impact on health-related QoL than having cancer, hypertension, or allergy [3]. Therefore, clinical indicators only are not sufficient to describe health status. This is also true for oral diseases and its consequences for oral health-related quality of life (OHRQoL). The two most prevalent oral diseases, caries and periodontal disease often do not cause symptoms in early stages. This might explain that clinical indicators of caries or periodontal involvement, such as number of decayed teeth, respectively tooth mobility and pocket depth are not strongly associated with impairment of OHRQoL [4, 5]. However, caries and periodontal disease are progressive processes, and lead to tooth loss if not treated adequately. Tooth loss will presumably cause functional impairment, for example, with regard to chewing and esthetics, depending on the location of tooth loss, which might ultimately affect QoL.

Besides generic health related QoL measures, specific oral health-related quality of life models and measures have been developed to assess the impact of oral disease on OHRQoL [6]. For example Locker [7] described a model based on the WHO classification of impairment, disability and handicap. The Oral Health Impact Profile (OHIP), one of the most popular measures, was developed on basis of this model [8].

Although OHRQoL assessment by validated questionnaires is more common nowadays, a recent systematic review of the literature resulted in only sparse information regarding OHRQoL treatment outcomes of reconstructive dentistry for partially edentate patients [9]. However, besides using OHRQoL measures to evaluate treatment outcomes it is in the first place important to know to what extent tooth loss actually affects OHRQoL. This enables development of clinical decision making in public health and to provide appropriate oral health care. Several population surveys include 'number of teeth' in statistical models analyzing impact on OHRQoL, but this parameter appears

not always to be the most prominent predictor. For example, in a population of older adults in Sri Lanka, Ekanayake and Perera [10] found only a weak association between tooth loss and other clinical parameters on the one hand and oral impacts on the other hand. This suggests that other factors such as age, gender or cultural background of the patient play an important role in the perception of health [10, 11]. In contrast, in a large Japanese study Ide et al. [12] found a strong correlation between the number of missing teeth and higher OHIP scores suggesting impairment of OHRQoL.

The aim of the present study is to systematically review the literature and to analyse the relationship between the number and location of missing teeth and oral health-related quality of life (OHRQoL). It was hypothesized that tooth loss is associated with an impairment of OHRQoL. Secondly, it was hypothesized that location and distribution of remaining teeth play an important role in this.

Methods

Search strategy

In this study the Cochrane guidelines for the conduct of a systematic review were used [13]. Medline, PubMed, Embase and the Cochrane Library were initially searched for papers published from 1990 to June 2008 to answer the following question: is tooth loss associated with impairment of people's oral health-related quality of life and what is the role of location and distribution of tooth loss in this relationship? The search was updated in July 2009. A broad search strategy was pursued to capture as many relevant studies as possible. For this reason not only studies with subject matter 'tooth loss' but also studies with subject matter 'management of tooth loss' were searched for. The following keywords were used: 'quality of life', 'patient satisfaction', 'tooth loss', 'partial edent*', 'partial denture', 'implant' and 'prosthodont*'. MeSH terms were used if the search machine of the database permitted this. The full search strategy for PubMed is presented in Table 2.1. As in the early nineteen nineties quality of life was not a general used concept in dentistry, patient satisfaction was used as a proxy of quality of life. Although RCT's provide the highest level of evidence, this study design is in most cases not feasible for tooth loss. Therefore, data from observational studies like cross-sectional studies, case series, case-control and cohort studies are included in this review [14]. Only publications in English were selected. Reference lists of the eventually included

papers were hand-searched to identify additional relevant studies and possible false exclusions, until no new applicable titles appeared (saturation).

Table 2.1 PubMed search using MeSH terms

#1	("Quality of Life"[Mesh]) OR ("Patient Satisfaction"[Mesh])
#2	("Denture, Partial"[Mesh]) OR ("Denture, Partial, Fixed"[Mesh]) OR ("Dental Implants"[Mesh]) OR ("Dental Implants, Single-Tooth"[Mesh]) OR ("Dental Prosthesis, Implant-Supported"[Mesh]) OR ("Osseointegration"[Mesh]) OR ("Dental Implantation"[Mesh])
#3	("Jaw, Edentulous, Partially"[Mesh]) OR ("Tooth Loss"[Mesh])
#4	(#1 AND #2)
#5	(#1 AND #3)
#6	(#4 OR #5)

Study selection

Two readers (NHJC and AEG) independently selected references on the basis of titles and abstracts for the impact of tooth loss or tooth replacement on oral health-related quality of life using predefined exclusion criteria. Excluded were case reports, (narrative) reviews, non-human studies, non-oral implants (hip/ knee) studies, studies exclusively dealing with edentulous subjects/full (over)dentures, restorations not replacing teeth, orthodontics, periodontics, tooth wear, and medical compromised patient groups (e.g. irradiated patients and systemic diseases like diabetes). The readers were calibrated by discussion sessions after assessment of every 10 abstracts. If necessary, the list of excluding criteria was revised after a discussion session and those abstracts already screened were re-subjected to the selection process. This procedure was repeated until no new exclusion criteria turned up. Agreement between readers was determined using κ statistics. Disagreements were resolved by discussion and if not resolved a third reader was called in (PFA) and reviewed the manuscript independently. In cases of doubt, the reference was included. This approach was applied in all selection steps.

After abstract selection, full-text copies of the selected papers were made. These full-text papers were assessed independently by the two readers (NHJC and AEG) using a pilot-tested assessment form. Full-text paper exclusion criteria are outlined in Table

2.2. In this phase of the review process, if considered necessary, authors were contacted to clarify issues of their published research that gave rise to uncertainty.

Table 2.2 Exclusion criteria applied for eligibility assessment of full-text papers and number of exclusions

Reason for exclusion (eligibility)	Number of studies excluded
Incomplete sample information	10
<ul style="list-style-type: none"> • Sampling method unclear • Age distribution not stated • Gender distribution not stated 	
Insufficient methods (information)	26
<ul style="list-style-type: none"> • No clinical examination or validated 'self tooth count' form not used • Measure for satisfaction or OHRQoL not clearly described • Details of replacement not explicit 	
OHRQoL outcomes not related to (management of) tooth loss	73
Mistakenly included on the basis of abstract	20
Total	129

Synthesis of data

Studies were grouped on the basis of OHRQoL instruments used: Oral Health Impact Profile (OHIP), Oral Impact on Daily Living (OIDP), Geriatric Oral Health Assessment Index (GOHAI), Dental Impact of Daily Living (DIDL), OHQoL-UK[®], and others. The rationale for this grouping was the incompatibility of the various instrument scoring systems. Besides that, the categorizations of number of teeth as used in the original studies should be comparable. Subsequently, for studies presenting continuous outcomes (e.g. mean scores) meta-analysis was deemed possible if a variance estimate was presented such as SD or SE. For studies presenting dichotomized outcomes pooling was considered possible if numbers with or without outcome property (e.g. with or without impact) were presented.

For continuous data Cochran's Q [15] was calculated to test for heterogeneity. Summary effects were calculated with DerSimonian's method [16] in case of heterogeneous data and weighted average was calculated for homogeneous data.

For dichotomized data Woolf's test [17] for heterogeneity was used. Again, summary effects were calculated by DerSimonian's method [16] in case of heterogeneous data, but the Mantel-Haenszel test [18] was used for homogenous data.

All studies, including those not suitable for meta-analyses, were subjected to qualitative analyses. For qualitative analyses study characteristics, main outcomes concerning missing teeth and possible other relevant outcomes were extracted and grouped according to OHRQoL instrument used.

Results

Study selection and study characteristics

Details of the identification, screening and selection process are presented in Figure 2.1. A total of 396 references was identified through the searching of Medline, 516 through PubMed, 134 through Embase, and 149 through the Cochrane Library. Duplicate references were removed and eventually 783 references remained. The search update resulted in 141 additional abstracts. For abstract assessment complete agreement was seen for 884 abstracts (inter-reader agreement $\kappa = 0.84$; SE = 0.03) and consensus was reached in 40 cases (23 included, 17 excluded). After reviewing the abstracts, 150 studies were included in the study. Reference tracking revealed 24 additional papers adding up to a total of 174 full-text papers for eligibility assessment. Finally, after assessment of full-text articles, 45 papers were included for review (inter-reader agreement $\kappa = 0.68$; SE = 0.06). In 5 cases the third reader's judgement was decisive. As the present study is only dealing with tooth loss, and not with management of tooth loss, studies exclusively dealing with the latter were not used for the present analyses. Characteristics and main outcomes of the 35 remaining studies [4, 5, 10, 12, 19-49] are presented in Table 2.3.

Quantitative analyses

In summary, 10 studies reporting on 13 different samples were eligible for meta-analysis resulting in 6 separate syntheses on the outcomes of 4 OHRQoL instruments (Table 2.3, Figures 2.2 to 2.7).

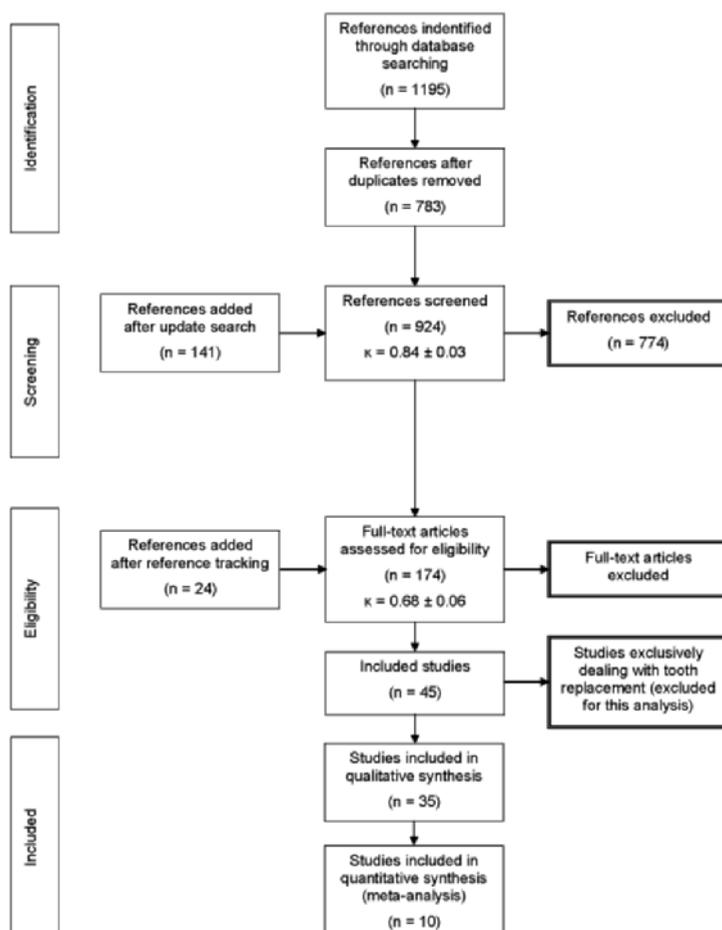


Figure 2.1 Flow chart outlining the search strategy and results along various steps.

Oral Health Impact Profile (OHIP) studies

Two studies [25, 43] reported OHIP data as mean total scores (SD) from three different samples of three cross-sectional surveys from the UK (n = 3662), Australia (n = 3406) and Finland (n = 5987). In these analyses mean OHIP scores of subjects with 25-32 teeth were compared with mean OHIP scores of subjects having 21-24 teeth, 17-20 teeth, 9-16 teeth and 1-8 teeth (Figure 2.2). Data are presented as differences in mean OHIP scores per group for each sample. This meta-analysis shows that the fewer teeth are present the higher the impact on OHRQoL with a marked deterioration once the number of remaining teeth drops below 17.

Table 2.3 Summary of the 6 meta-analyses

Comparison	Summary effect	95% CI	p-value for heterogeneity test	Model used
Meta analysis 1 [25, 43]				
<i>Continuous data (difference in mean OHIP total scores)</i>				
<i>Total n = 12965</i>				
<i>Reference group: 25-32 teeth</i>				
1-8 teeth	3.37	1.37-5.38	<0.001	random effect
9-16 teeth	3.08	1.37-4.80	<0.001	random effect
17-20 teeth	1.89	-0.03-3.82	<0.001	random effect
21-24 teeth	1.05	0.07-2.02	<0.001	random effect
Meta analysis 2 [25, 26]				
<i>Dichotomized data (Odds ratio for having an OHIP impact)</i>				
<i>Total n = 6821</i>				
<i>Reference group: complete dentition or ≥ 25 teeth</i>				
Incomplete or < 25 teeth	3.45	2.93-4.05	0.975	fixed effect
Meta analysis 3 [5, 24, 45]				
<i>Dichotomized data (Odds ratio for having an OIDP impact)</i>				
<i>Total n = 2204</i>				
<i>Reference group ≥ 21 teeth</i>				
≤ 10 teeth	2.01	1.43-2.83	0.962	fixed effect
> 10 and < 21 teeth	1.63	1.23-2.17	0.794	fixed effect
Meta analysis 4 [5, 45]				
<i>Dichotomized data (Odds ratio for having an OIDP impact)</i>				
<i>Total n = 1184</i>				
<i>Reference groups 9-16 NOPs/4-8 POPs/no UAS</i>				
0-8 NOPs	1.99	1.39-2.86	0.279	fixed effect
0-3 POPs	1.66	1.16-2.37	0.808	fixed effect
UAS	1.82	0.68-4.87	0.025	random effect
NOP = natural occluding pair; POP = posterior occluding pair; UAS = unrestored anterior space				
Meta analysis 5 [38, 46]				
<i>Continuous data (difference in mean GOHAf total scores)</i>				
<i>Total n = 435</i>				
<i>Reference group: 20-32 teeth</i>				
0-19 teeth	9.78	7.38-12.18	0.157	fixed effect
Meta analysis 6 [31, 35]				
<i>Continuous data (difference in mean OHQoL-UK[®] total scores)</i>				
<i>Total n = 2738</i>				
<i>Reference group: 20-32 teeth</i>				
0-19 teeth	4.56	3.67-5.44	0.912	fixed effect

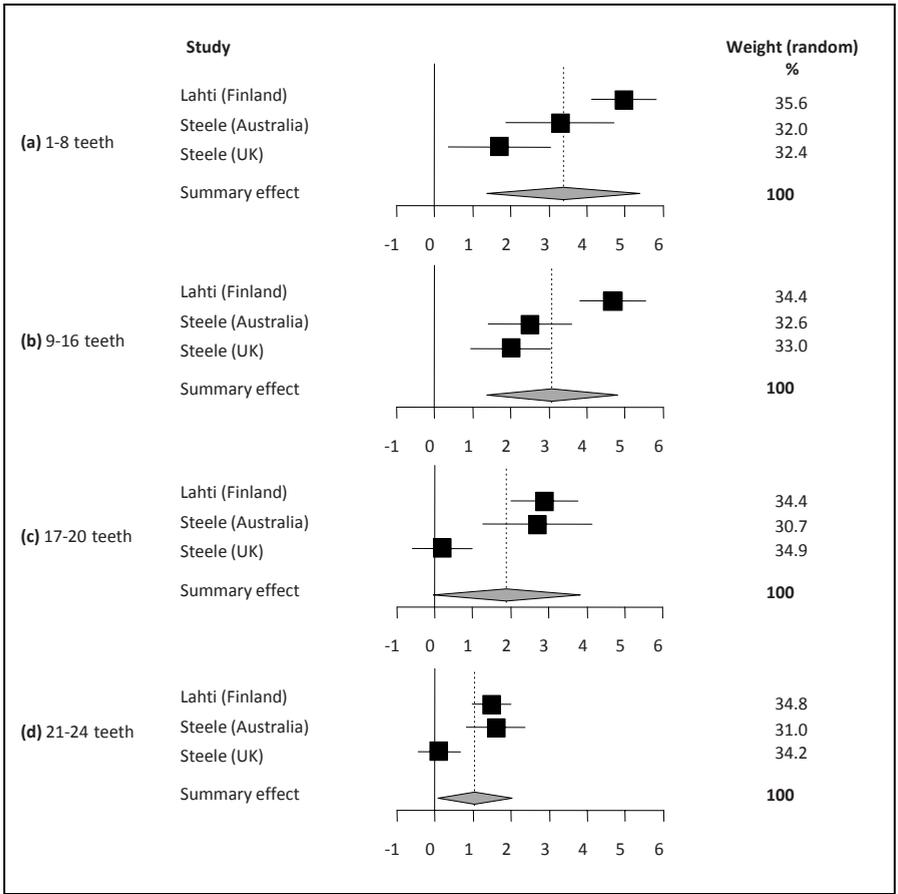


Figure 2.2 Synthesis of two studies presenting differences in mean OHIP total scores. Forest plots presenting differences in mean OHIP total scores of categories of number of present teeth for three samples (total n = 12965) [25, 43]. The category 25-32 teeth was used as reference. Relative box size indicates the weight of the study: **(a)** 1-8 teeth (heterogeneity $Q = 16.75$; $df = 2$), **(b)** 9-16 teeth (heterogeneity $Q = 17.80$; $df = 2$), **(c)** 17-20 teeth (heterogeneity $Q = 22.06$; $df = 2$), **(d)** 21-24 teeth (heterogeneity $Q = 15.51$; $df = 2$).

Two studies [25, 26], including in total 6821 subjects, reported OHIP data as prevalence of impacts according to dental status (Figure 2.3). One study categorized dental status as complete dentition vs. one or more missing teeth [26] whereas the other study categorized dental status as 32-25 teeth vs. 0-24 teeth [25]. This pooling was made on the assumption that categories were comparable.

Differences in impact scores between the two categories in each study are presented as Odds Ratios. The pooled data indicate that loss of teeth is associated with a threefold likelihood of reporting an impact on OHRQoL.

Oral Impact on Daily Living (OIDP) studies

The three studies [5, 24, 45], including in total 2204 subjects, that used OIDP scores as an outcome measure for OHRQoL are presented in Figure 2.4. In all three studies OIPD scores were calculated by multiplying frequency by severity of the impact and summing up the scores of ten areas of daily activities. Three categories of dental status were presented namely 0/1-10, 11-20 and 21-32 teeth present. Differences between the categories were presented as Odds Ratios with having an impact as dependent variable. Subjects with fewer than 10 teeth were twice as likely to report an impact compared with subjects having 21-32 teeth; subject with 11-20 teeth were 1.5 times more likely to report an impact.

Two of the OIDP studies [5, 45] (total number of subjects = 1184) presented OHRQoL data in relation to occluding pairs and location of tooth loss: natural occluding pairs (NOPs), posterior occluding pairs (POPs), and presence of 'unrestored anterior spaces' (UAS). Differences between categories are presented as Odds Ratio's with having an impact as dependent variable (Figure 2.5). Reporting an impact on their daily life was twice as likely for subjects with 0-8 NOPs than for subjects having 9-16 NOPs and 1.6 times more likely for subjects having 0-3 POPs than for subjects having 4-8 POPs. Subjects having one or more unrestored anterior spaces were 1.8 times more likely to report any impact on their daily life.

Geriatric Oral Health Assessment Index (GOHAI) studies

The two GOHAI studies [38, 46] (total n = 435) in this meta-analysis used mean total scores as outcome measure (Figure 2.6). Differences in the mean scores show that GOHAI scores were higher for subjects with 20 or more teeth, indicating better OHRQoL.

Oral Health Quality of Life-UK (OHQoL-UK[®]) studies

Two studies [31, 35] reported mean total scores for OHQoL-UK[®] for four different samples from the UK, Syria, Egypt and Saudi Arabia with a total of 2783 subjects (Figure 2.7). Differences between mean total scores of two categories of dental status, namely 0-19 teeth present vs. 20 and more teeth. It should be noted that the UK sample contributes 91% to the summary effect.

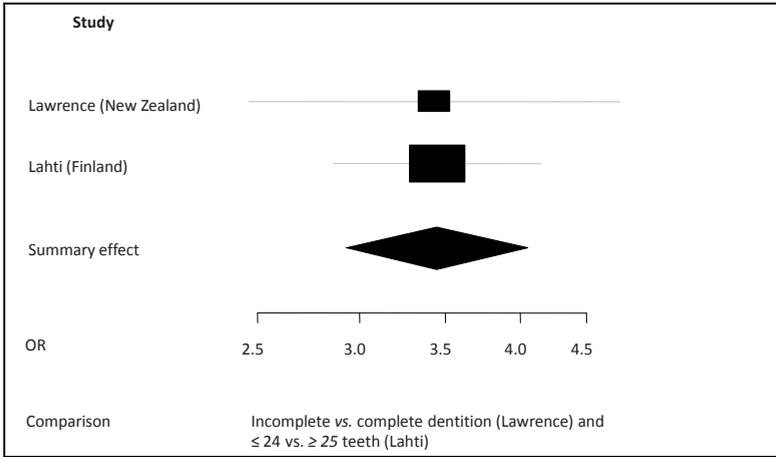


Figure 2.3 Synthesis of two OHIP studies presenting Odds Ratio's. Forest plot presenting Odds Ratio's (OR) for having OHIP impacts (fairly/very often) of two categories of number of present teeth (incomplete vs. complete [26] and ≤ 24 vs. ≥ 25 [25]) in two samples (total n = 6821). Relative box size indicates weight of the study (heterogeneity $X^2 = 0,00$; $df = 1$).

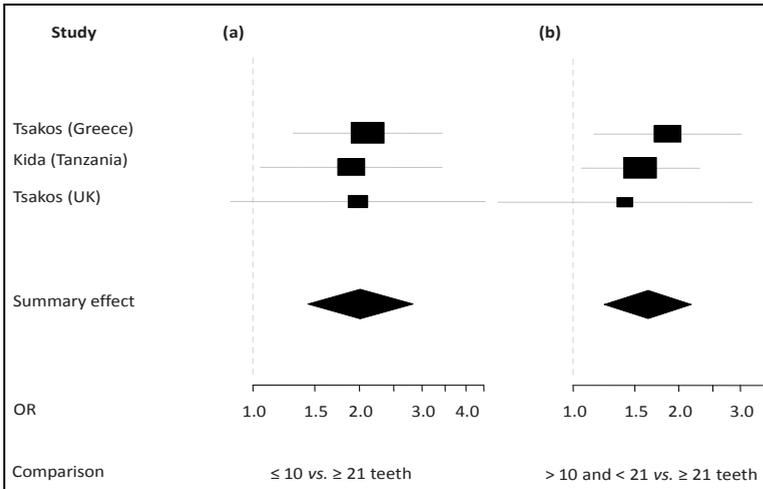


Figure 2.4 Synthesis of three OIDP studies presenting Odds Ratio's. Forest plots presenting Odds Ratio's (OR) for having any impact on OIDP of three categories of number of present teeth in three samples (total n = 2204) [5, 24, 45]. Relative box size indicates weight of the study. **(a)** ≤ 10 vs. ≥ 21 teeth (heterogeneity $X^2 = 0,08$; $df = 2$), **(b)** > 10 and < 21 vs. ≥ 21 teeth (heterogeneity $X^2 = 0,46$; $df = 2$).

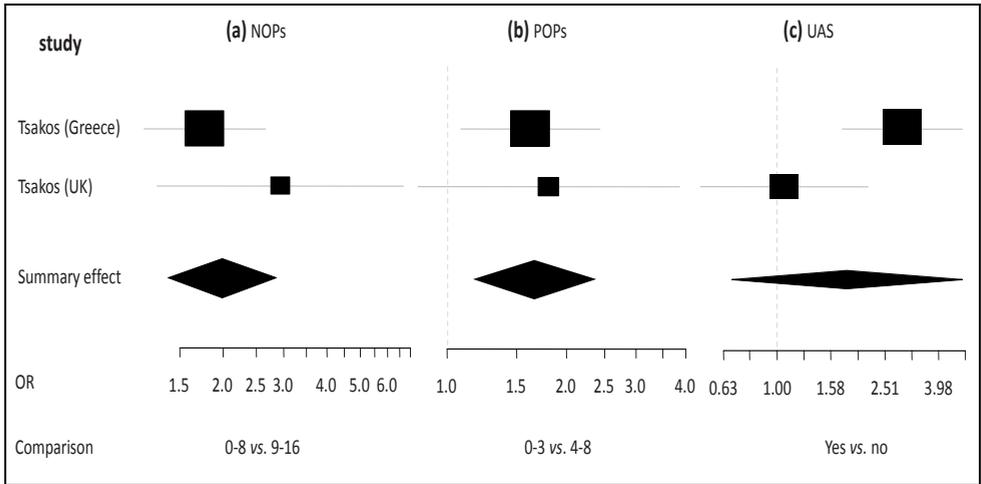


Figure 2.5 Synthesis of two ODP studies presenting Odds Ratio's in relation to occluding pairs and location.

Forest plots presenting Odds Ratio's (OR) for having any impact on ODP of two categories of number of natural occluding pairs (NOPs) and posterior occluding pairs (POPs) and unrestored anterior spaces (UAS) in two samples (total n = 1184) [5, 45]. Relative box size indicates weight of the study. **(a)** NOPs 0-8 vs. 9-16 (heterogeneity $X^2 = 1.17$; $df = 1$), **(b)** POPs 0-3 vs. 4-8 (heterogeneity $X^2 = 0.06$; $df = 1$), **(c)** UAS yes vs. no (heterogeneity $X^2 = 5.03$; $df = 1$).

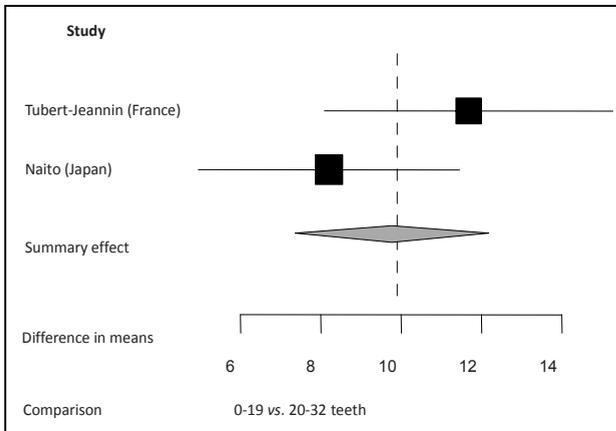


Figure 2.6 Synthesis of two studies presenting differences in mean GOHAI total scores.

Forest plot presenting differences in mean GOHAI total scores between two categories of number of present teeth: 0-19 teeth vs. 20+ teeth in two samples (total n = 435) [38, 46]. Relative box size indicates weight of the study (heterogeneity $Q = 2.00$; $df = 1$).

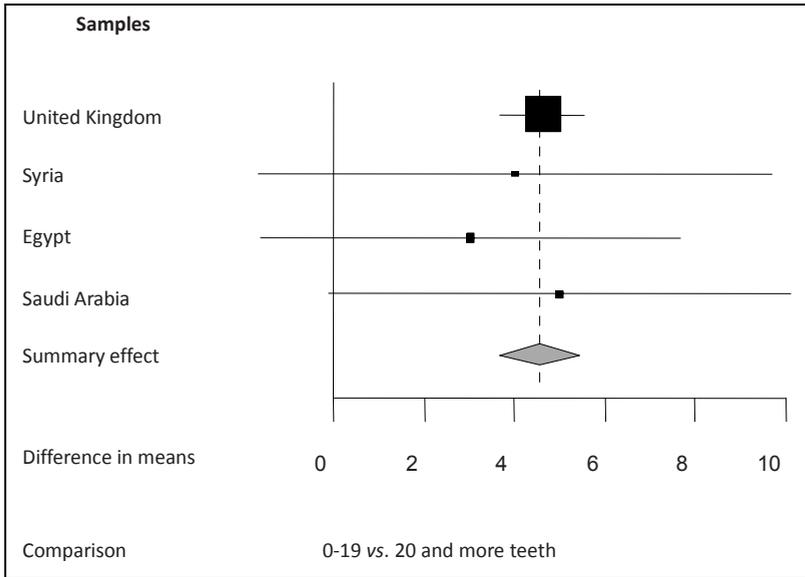


Figure 2.7 Synthesis of two studies presenting differences in mean OHQoL-UK[®] total scores in four samples.

Forest plot presenting differences in mean OHQoL-UK[®] total scores between two categories of numbers of present teeth: 0-19 teeth vs. 20 and more teeth in four samples (total n = 2738) described in two studies [31, 35]. Relative box size indicates weight of the study (heterogeneity $Q = 0.15$; $df = 3$).

Qualitative analyses

The studies that failed the criteria for meta-analysis were only analysed qualitatively.

Number of teeth

Most included studies found statistically significant associations between missing teeth and unfavourable OHQoL scores, independent of the instrument used or the country of investigation. However, the results of a few studies were not conclusive: Hassel et al. [23] reported no statistically significant difference in OHIP scores between dentate and edentate institutionalized elderly, but statistically significant higher OHIP scores for subject with 'less teeth in static occlusion';

Mesas et al. [37] reported only statistically significant differences in GOHAI scores between edentulous and dentate subjects for the 'physical' dimension but not for the 'social' and 'worry' dimension; Tsakos et al. [5] and Sheiham et al. [41], reporting on

the same sample, found no statistically significant association between number of present teeth and having an OIPD impact in British adults, but lower numbers of anterior occluding pairs and natural occluding pairs were associated with OHRQoL impairment.

Occluding pairs and location of missing teeth

Statistically significant positive correlations between number of occluding pairs and OHRQoL were found in all 10 studies (dealing with 9 different samples) reporting on this subject [5, 20, 21, 23, 27, 29, 36, 37, 44, 45] (Table 2.4).

Five studies reported on OHRQoL and location of missing teeth, four of them [5, 40, 45, 48] reporting higher impact for missing anterior teeth. One of them [44] indicated comparable impact for missing posterior occluding pairs and anterior occluding pairs (Table 2.5).

Table 2.4 Summary of studies reporting on occluding pairs

First author, year	Population, sample n, (% females)	Subject of the study	Main outcomes regarding occluding pairs
<i>OHIP-49 (Oral Health Impact Profile)</i>			
Baba, 2008a ^{CS} [20]	Japanese adults with shortened dental arches	Relationship between shortened dental arches and OHRQoL	a: Dose response relationship between number of missing posterior teeth and OHRQoL in subjects with shortened dental arches. Missing posterior units is related to impairment of OHRQoL.
Baba, 2008b ^{CS} [21]	n = 155 (70)		b: Patterns of missing occluding units likely to be related to the OHRQoL impairment in shortened dental arch subjects with the presence of first molar contact having a particularly important role.
Hassel, 2006 ^{CS} [23]	German institutionalized elderly n = 159 (81)	Dental and non-dental factors on OHRQoL of institutionalized elderly	Less teeth in static occlusion related to impairment of OHRQoL.
Locker, 1994 ^{LT} [29]	Canadian older adults n = 312 (54)	Clinical and subjective indicators of oral health status and OHRQoL	Having fewer functional units associated with impairment of OHRQoL.
<i>GOHAI (Geriatric Oral Health Assessment Index)</i>			
Mesas, 2008 ^{CS} [37]	Brazilian urban elderly n = 267 (60)	Dental and non-dental factors on OHRQoL	Absence of posterior occlusion associated with impairment of OHRQoL but only statistically significant for 'physical' dimension and not for the 'social' and 'worry' dimensions.
Swoboda, 2006 ^{CS} [44]	American low income elderly n = 733 (56)	Dental and non-dental predictors on OHRQoL	OHRQoL positively related to the total number of occluding pairs, molar pairs occluding, anterior pairs occluding, and premolar pairs occluding.

OIDP (Oral Impact on Daily Performance)

Tsakos, 2006 ^{CS} [5]	British non-institutionalized elderly (subsample of Sheiham, 2001) n = 736 (48)	Clinical correlates of OHRQoL	OHRQoL significantly related to the total number of occluding pairs and to the number of anterior occluding pairs but not to the number of posterior occluding pairs.
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Tsakos, 2004 ^{CS} [45]	Greek non-institutionalized elderly n = 448 (64)	Relationship between clinical dental measures and OHRQoL	OHRQoL significantly related to the total number of occluding pairs and to the number of posterior occluding pairs.
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Ad hoc satisfaction questionnaires

Leake, 1994 ^{CS} [27]	American and Canadian older adults n = 338 (55)	Assessment of relationship between oral function and posterior dental units	Low number of posterior units was associated with embarrassment and dissatisfaction on chewing and appearance, indicating OHRQoL impairment.
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Meeuwissen, 1995 ^{CS} [36]	Dutch dentate older adults n = 320 (59)	Satisfaction with reduced dentitions	Fewer posterior occluding units associated with lower satisfaction scores, indicating OHRQoL impairment.
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^{CS} = cross-sectional study; ^{LT} = longitudinal study; ^{CO} = cohort study

Table 2.5 Summary of studies reporting the location of missing teeth

First author, year	Population, sample n (% females)	Subject of the study	Main outcomes regarding location of missing teeth
<i>OHIP-49 (Oral Health Impact Profile)</i>			
Walter, 2007 ^{CS} [48]	Canadian rural adults n = 140 (64)	Clinical and socio-demographic variables and OHRQoL	One or more natural posterior teeth missing not associated with OHRQoL impairment whereas one or more natural anterior teeth missing was associated with OHRQoL impairment.
<i>OHIP-14 (Oral Health Impact Profile short version)</i>			
Pallegedara, 2008 ^{CS} [40]	Sinhalese non-institutionalized elderly n = 630 (54)	Tooth loss, denture status and OHRQoL	'Presence of anterior spaces' more negative impact on the OHRQoL than 'missing posterior teeth'.
<i>GOHAI (Geriatric Oral Health Assessment Index)</i>			
Swoboda, 2006 ^{CS} [44]	American low income elderly n = 733 (56)	Dental and non-dental predictors on OHRQoL	Comparable impact on OHRQoL of the number of molar pairs occluding, premolar pairs occluding and anterior pairs occluding.
<i>OIDP (Oral Impact on Daily Performance)</i>			
Tsakos, 2004 ^{CS} [45]	Greek non-institutionalized elderly n = 448 (48)	Relationship between clinical dental measures and OHRQoL	Having 'unfilled anterior spaces' more impact on OHRQoL than having few (0-3) posterior occluding pairs.
Tsakos, 2006 ^{CS} [5]	British non-institutionalized elderly n = 736 (64)	Clinical correlates of OHRQoL	Having few anterior occluding pairs (0-2) more impact on OHRQoL than having few posterior occluding pairs (0-3).

^{CS} = cross-sectional study; ^{LT} = longitudinal study; ^{CO} = cohort study; ^{VA} = validation study

Discussion

Chronic diseases such as dental caries are still highly prevalent in older adults, and the risk of tooth loss in old age is high. Oral health care with an intervention led focus is costly, and demand for this care may increase as the proportion of older dentate adults increases. Demand for treatment is not well correlated with objectively determined treatment need, and it has been recognized that objective measures of disease are not good predictors of demand. It would appear that loss of teeth is not as acceptable as in previous generations, and this will potentially influence future demand for treatment [50].

As public resources for dental treatment becomes increasingly scarce, new paradigms for assessment of oral health have been developed. The use of OHRQoL measures has increased significantly over the past 15 years. By incorporating subjective and objective assessment, our understanding of the consequences of oral disease and tooth loss has improved [51]. Subjective assessment has also been advocated as a means of targeting treatment resources provided through publically funded health services [52]. The rationale for this is to prioritise scarce financial resources towards those eligible patients most likely to benefit from a particular therapy. It is known that the impact of disease on quality of life is highly variable, and thus, the impact of a treatment intervention will also vary. An example of this is in the use of dental implants to retain prostheses in edentulous patients. Dental status (in this case, edentate) does not necessarily predict treatment outcome, and edentate patients satisfied with having complete dentures are unlikely to report significant extra benefit from having an expensive intervention (e.g., implant retained dentures) [53]. In this scenario, a health service provider would prefer to target resources towards patients who are dissatisfied with being edentate and have a poor self-reported health status. This is particularly relevant where a cure is not the objective of treatment, and the treatment goal is a reduction in morbidity associated with chronic disease.

Individual studies that have reported OHRQoL outcomes have identified predictors of poor OHRQoL. These included disease severity, dental status, social class and cultural background. Unfortunately, there has been a lack of uniformity in methods used to collect these data, and this has created some difficulty in generalizing the results of individual studies. A variety of OHRQoL measures have been used, ranging from ad hoc, non-validated questionnaires (mostly used in the early nineteen nineties when quality of life was not a general used concept in dentistry yet), to comprehensive measures based on conceptual models and validated for use in particular populations. In

the case of the latter measures, scoring systems have varied and been reported variously as prevalence, severity, and combinations of negative and positive perceptions of health. Finally, population studies have for the most part used shortened versions of validated measures such as the OHIP and this may lead to under-reporting of impacts.

Given these concerns, this review of the literature aimed to assimilate all of the available information on the relationship between tooth loss and OHRQoL in a systematic way using existing guidelines for conducting a systematic review. There were some limitations common to most systematic reviews, primarily difficulty in accessing literature not published in English. In order to minimize the possibility of publication bias, authors with acknowledged expertise in the field were contacted to determine if they had relevant data, which had not yet been published. They were also asked to clarify issues in their published research, which gave rise to uncertainty during the data extraction phase of the review. Accordingly, we believe that we have minimized the impact of reporting and publication bias.

Quality assessment of included studies was restricted to the use of exclusion criteria. These included minimal criteria of sample description (age and gender distribution) but not for example Socio Economic Status (SES). Other criteria indicating the quality of surveys, such as the number of observers, observer agreements, representativeness for larger samples, and the use of validated instruments were not always described, but were not used in the exclusion process. For instance, nine of the included studies were validation studies and these studies – presenting relevant data - would have been excluded in case the use of a validated instrument were an inclusion criterion. Although these studies were designed for another purpose, i.e. to test the psychometric properties of newly developed OHRQoL instruments, it was considered to be appropriate to use data on the number of missing teeth from these studies.

As far as we are aware of, this is the first systematic review and meta-analysis of the relationship between OHRQoL and tooth loss. Data from our systematic review and meta-analyses of observational studies provide fairly strong evidence that tooth loss is, on the whole, viewed negatively. This is a consistent finding, and appears to be independent of the OHRQoL measure used to assess subjective impact and context (e.g., country of residence). However, the severity of impairment of OHRQoL is probably context dependent [43]. Moreover, the severity of impairment might be associated with location and distribution of missing teeth, as suggested by the outcome of the meta-

analysis of data of a Greek and a British population (Figure 2.5). Although associated, the correlation between number of missing teeth and number of occluding pairs (which is a derivative of the distribution of missing teeth) is not linear [54]. Therefore, the impact of cultural background, and location and distribution of missing teeth remains subject for further exploration.

It should be acknowledged that all studies are reported at population level, and this may mask heterogeneity of scores at an individual level. The latter is reflected by the wide variation in outcome scores in the meta-analyses as presented in Figures 2.2 to 2.7. Despite this, it seems that the negative view of tooth loss may ultimately result in demand for treatment to replace missing teeth. This will include a demand for dental implant retained restorations and other costly forms of treatment with a high burden of maintenance. Acceptance of dental extraction and replacement of teeth with conventional removable dentures, either partial or complete, has diminished [50]; furthermore, ability to adapt to complete dentures in old age is also uncertain and best avoided if possible. This poses a considerable challenge for oral health care policy makers, and it is unlikely that all demand for high cost treatment interventions can be met solely by publicly funded healthcare.

The shortened dental arch concept has been described as means of providing sub-optimal, but acceptable level of oral function [55]. In limiting treatment goals to providing a shortened dental arch, costs of care can be minimized. The results of the review suggest that the number of occluding pairs of teeth is an important predictor of OHRQoL, and that the prevalence of negative impacts increases sharply once the number of teeth present drops below 20. It seems reasonable to suggest that application of the shortened dental arch approach is acceptable, particularly to older adults, and this may help inform public policy for oral health care in older age groups. The data also suggest that preventive strategies aimed at reducing tooth loss need to be reinforced. As reported by Petersen and Yamamoto [56], most oral diseases and chronic disease share common risk factors, and national health programs should incorporate disease prevention and health promotion using a common risk factor approach. Given the rising burden of chronic disease in an aging population, coupled with its negative impact on quality of life, this should receive urgent attention from policy makers.

Conclusions

This study provides fairly strong evidence that tooth loss is associated with impairment in OHRQoL. This association appeared to be independent from the OHRQoL instrument used and context (e.g. cultural background) of the included samples. However, the extent and severity of impairment seems to be context dependent. Moreover, this study indicates that not only number, but also location and distribution of missing teeth affect the severity of OHQoL impairment. Given the negative consequences of tooth loss on OHRQoL, it is important that disease prevention measures are promoted when formulating health policy for older adults. It is likely that there will be greater demand from patients for treatment aimed at preserving teeth. The effectiveness of preventive strategies will require further research, and further economic analysis of tooth replacement strategies is also required.

References

1. Decker SD, Schultz R, Wood D. Determinants of well-being in primary caregivers of spinal cord injured persons. *Rehabil Nurs.* 1989;14:6-8.
2. Sprangers MA, Aaronson NK. The role of health care providers and significant others in evaluating the quality of life of patients with chronic disease: a review. *J Clin Epidemiol.* 1992;45:743-60.
3. Mack F, Schwahn C, Feine JS, Mundt T, Bernhardt O, John U, et al. The impact of tooth loss on general health related to quality of life among elderly Pomeranians: results from the study of health in Pomerania (SHIP-O). *Int J Prosthodont.* 2005;18:414-9.
4. Marino R, Schofield M, Wright C, Calache H, Minichiello V. Self-reported and clinically determined oral health status predictors for quality of life in dentate older migrant adults. *Community Dent Oral Epidemiol.* 2008;36:85-94.
5. Tsakos G, Steele JG, Marcenes W, Walls AW, Sheiham A. Clinical correlates of oral health-related quality of life: evidence from a national sample of British older people. *Eur J Oral Sci.* 2006;114:391-5.
6. Allen PF. Assessment of oral health related quality of life. *Health Qual Life Outcomes.* 2003;1:40.
7. Locker D. Measuring oral health: a conceptual framework. *Community Dent Health.* 1988;5:3-18.
8. Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. *Community Dent Health.* 1994;11:3-11.
9. Thomason JM, Heydecke G, Feine JS, Ellis JS. How do patients perceive the benefit of reconstructive dentistry with regard to oral health-related quality of life and patient satisfaction? A systematic review. *Clin Oral Implants Res.* 2007;18 Suppl 3:168-88.
10. Ekanayake L, Perera I. The association between clinical oral health status and oral impacts experienced by older individuals in Sri Lanka. *J Oral Rehabil.* 2004;31:831-6.
11. Ashing-Giwa KT, Tejero JS, Kim J, Padilla GV, Hellemann G. Examining predictive models of HRQOL in a population-based, multiethnic sample of women with breast carcinoma. *Qual Life Res.* 2007;16:413-28.
12. Ide R, Yamamoto R, Mizoue T. The Japanese version of the Oral Health Impact Profile (OHIP)--validation among young and middle-aged adults. *Community Dent Health.* 2006;23:158-63.
13. Higgings JPT, Green S. *Cochrane Handbook for Systematic Reviews of Interventions.* The Cochrane Library. 2009;Version 5.0.2;www.cochrane-handbook.org.
14. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA.* 2000;283:2008-12.
15. Cochran WG. The Combination of Estimates from Different Experiments. *Biometrics.* 1954;10:101-29.
16. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials.* 1986;7:177-88.
17. Woolf B. On estimating the relation between blood group and disease. *Ann Hum Genet.* 1955;19:251-3.
18. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *J Natl Cancer Inst.* 1959;22:719-48.
19. Atchison KA, Dolan TA. Development of the Geriatric Oral Health Assessment Index. *J Dent Educ.* 1990;54:680-7.
20. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont.* 2008;21:72-4.
21. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. Patterns of missing occlusal units and oral health-related quality of life in SDA patients. *J Oral Rehabil.* 2008;35:621-8.
22. Bae KH, Kim HD, Jung SH, Park DY, Kim JB, Paik DI, et al. Validation of the Korean version of the oral health impact profile among the Korean elderly. *Community Dent Oral Epidemiol.* 2007;35:73-9.
23. Hassel AJ, Koke U, Schmitter M, Rammelsberg P. Factors associated with oral health-related quality of life in institutionalized elderly. *Acta Odontol Scand.* 2006;64:9-15.

24. Kida IA, Astrom AN, Strand GV, Masalu JR, Tsakos G. Psychometric properties and the prevalence, intensity and causes of oral impacts on daily performance (OIDP) in a population of older Tanzanians. *Health Qual Life Outcomes*. 2006;4:56.
25. Lahti S, Suominen-Taipale L, Hausen H. Oral health impacts among adults in Finland: competing effects of age, number of teeth, and removable dentures. *Eur J Oral Sci*. 2008;116:260-6.
26. Lawrence HP, Thomson WM, Broadbent JM, Poulton R. Oral health-related quality of life in a birth cohort of 32-year olds. *Community Dent Oral Epidemiol*. 2008;36:305-16.
27. Leake JL, Hawkins R, Locker D. Social and functional impact of reduced posterior dental units in older adults. *J Oral Rehabil*. 1994;21:1-10.
28. Leao A, Sheiham A. Relation between clinical dental status and subjective impacts on daily living. *J Dent Res*. 1995;74:1408-13.
29. Locker D, Slade G. Association between clinical and subjective indicators of oral health status in an older adult population. *Gerodontology*. 1994;11:108-14.
30. Mason J, Pearce MS, Walls AW, Parker L, Steele JG. How do factors at different stages of the lifecourse contribute to oral-health-related quality of life in middle age for men and women? *J Dent Res*. 2006;85:257-61.
31. McGrath C, Alkhatib MN, Al-Munif M, Bedi R, Zaki AS. Translation and validation of an Arabic version of the UK oral health related quality of life measure (OHQoL-UK) in Syria, Egypt and Saudi Arabia. *Community Dent Health*. 2003;20:241-5.
32. McGrath C, Bedi R. Can dentures improve the quality of life of those who have experienced considerable tooth loss? *J Dent*. 2001;29:243-6.
33. McGrath C, Bedi R. An evaluation of a new measure of oral health related quality of life--OHQoL-UK(W). *Community Dent Health*. 2001;18:138-43.
34. McGrath C, Bedi R. Population based norming of the UK oral health related quality of life measure (OHQoL-UK). *Br Dent J*. 2002;193:521-4; discussion 17.
35. McGrath C, Bedi R. Why are we "weighting"? An assessment of a self-weighting approach to measuring oral health-related quality of life. *Community Dent Oral Epidemiol*. 2004;32:19-24.
36. Meeuwissen JH, van Waas MA, Meeuwissen R, Käyser AF, van 't Hof MA, Kalk W. Satisfaction with reduced dentitions in elderly people. *J Oral Rehabil*. 1995;22:397-401.
37. Mesas AE, de Andrade SM, Cabrera MA. Factors associated with negative self-perception of oral health among elderly people in a Brazilian community. *Gerodontology*. 2008;25:49-56.
38. Naito M, Suzukamo Y, Nakayama T, Hamajima N, Fukuhara S. Linguistic adaptation and validation of the General Oral Health Assessment Index (GOHAI) in an elderly Japanese population. *J Public Health Dent*. 2006;66:273-5.
39. Oliveira BH, Nadanovsky P. Psychometric properties of the Brazilian version of the Oral Health Impact Profile-short form. *Community Dent Oral Epidemiol*. 2005;33:307-14.
40. Pallegedara C, Ekanayake L. Effect of tooth loss and denture status on oral health-related quality of life of older individuals from Sri Lanka. *Community Dent Health*. 2008;25:196-200.
41. Sheiham A, Steele JG, Marcenes W, Tsakos G, Finch S, Walls AW. Prevalence of impacts of dental and oral disorders and their effects on eating among older people; a national survey in Great Britain. *Community Dent Oral Epidemiol*. 2001;29:195-203.
42. Steele JG, Ayatollahi SM, Walls AW, Murray JJ. Clinical factors related to reported satisfaction with oral function amongst dentate older adults in England. *Community Dent Oral Epidemiol*. 1997;25:143-9.
43. Steele JG, Sanders AE, Slade GD, Allen PF, Lahti S, Nuttall N, et al. How do age and tooth loss affect oral health impacts and quality of life? A study comparing two national samples. *Community Dent Oral Epidemiol*. 2004;32:107-14.
44. Swoboda J, Kiyak HA, Persson RE, Persson GR, Yamaguchi DK, MacEntee MI, et al. Predictors of oral health quality of life in older adults. *Spec Care Dentist*. 2006;26:137-44.
45. Tsakos G, Marcenes W, Sheiham A. The relationship between clinical dental status and oral impacts in an elderly population. *Oral Health Prev Dent*. 2004;2:211-20.
46. Tubert-Jeannin S, Riordan PJ, Morel-Papernot A, Porcheray S, Saby-Collet S. Validation of an oral health quality of life index (GOHAI) in France. *Community Dent Oral Epidemiol*. 2003;31:275-84.
47. Tubert-Jeannin S, Riordan PJ, Morel-Papernot A, Roland M. Dental status and oral health quality of life in economically

disadvantaged French adults. *Spec Care Dentist*. 2004;24:264-9.

48. Walter MH, Woronuk JI, Tan HK, Lenz U, Koch R, Boening KW, et al. Oral health related quality of life and its association with sociodemographic and clinical findings in 3 northern outreach clinics. *J Can Dent Assoc*. 2007;73:153.

49. Wong MC, McMillan AS. Tooth loss, denture wearing and oral health-related quality of life in elderly Chinese people. *Community Dent Health*. 2005;22:156-61.

50. Cronin M, Meaney S, Jepson NJ, Allen PF. A qualitative study of trends in patient preferences for the management of the partially dentate state. *Gerodontology*. 2009;26:137-42.

51. Locker D. Applications of self-reported assessments of oral health outcomes. *J Dent Educ*. 1996;60:494-500.

52. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient-based

outcome measures for use in clinical trials. *Health Technol Assess*. 1998;2:i-iv, 1-74.

53. Allen PF, Thomason JM, Jepson NJ, Nohl F, Smith DG, Ellis J. A randomized controlled trial of implant-retained mandibular overdentures. *J Dent Res*. 2006;85:547-51.

54. Nguyen TC, Witter DJ, Bronkhorst EM, Pham L, Creugers N.H.J.. Dental functional status in a Southern Vietnamese adult population - an analysis by a combined quantitative and qualitative classification system. *Int J Prosthodont* 2011;24:30-7.

55. Gottfredsen K, Walls AW. What dentition assures oral function? *Clin Oral Implants Res*. 2007;18 Suppl 3:34-45.

56. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol*. 2005;33:81-92.

Chapter 3

An observational cohort study on shortened dental arches – clinical course during a period of 27-35 years

Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. An observational cohort study on shortened dental arches-clinical course during a period of 27-35 years. *Clinical Oral Investigations*. 2013;17:859-66.

Abstract

Aim

To investigate the clinical course of shortened dental arches (SDA group) compared to SDAs plus removable denture prosthesis (SDA plus RDP group) and complete dental arches (CDA group; controls).

Methods

Data (numbers of direct and indirect restorations, endodontic treatments, tooth loss and tooth replacements) were extracted from patient records of subjects attending the Nijmegen Dental School who previously participated in a cohort study on shortened dental arches with three to four posterior occluding pairs (POPs).

Results

Records of 35% of the original cohort were retrievable. At the end of the follow-up (27.4 ± 7.1 years) 20 out of 23 SDA subjects still had SDA with 3-4 POPs compared to 6 out of 13 for SDA plus RDP subjects (follow-up 32.6 ± 7.3 years). Sixteen out of 23 CDA subjects still had CDA; none of them lost more than one POP (follow-up 35.0 ± 5.6 years). SDA group lost 67 teeth: 16 were not replaced, 16 were replaced by FDP, and 35 teeth (lost in three subjects) replaced by RDP. Mean number of treatments per year in SDA subjects differed not significantly compared to CDA subjects except for indirect restorations in the upper jaw.

Conclusion

Shortened dental arches can last for 27 years and over. Clinical course in SDA plus RDP is unfavourable, especially when RDP-related interventions are taken into account.

Background

The shortened dental arch concept is a potentially cost-effective approach in the management of reduced dentitions. This concept is globally accepted, but not widely practiced [1]. A body of mainly circumstantial evidence shows that shortened dental arches, comprising all anterior teeth and three to five occluding units, provide a stable and functional dentition with respect to chewing ability, aesthetics and oral comfort [2-5]. The functionality of shortened dental arches has been reflected in outcomes of studies on oral health-related quality of life (OHRQoL). The outcomes are rather controversial: on the one hand, shortened dental arches are found to be related to OHRQoL impairment [6], especially when first molar contacts were absent [7], on the other hand, subjects with a shortened dental arch reported to be satisfied with their oral status [8].

Oral health care aims at the retention of at least a functional and natural dentition throughout life. Therefore, besides functionality also longevity of shortened dental arches should also be taken into account when considering application of the shortened dental arch concept. The fact that shortened dental arch subjects have lost molars in the past implicitly indicates an increased risk for dental diseases in these subjects. It is reasonable to expect that this predisposition to dental diseases is not eliminated after applying the shortened dental arch concept and hence necessitate more treatment in course of time including additional tooth extractions. Further tooth loss may endanger the longevity of the shortened dental arch status and thus compromise oral function.

The consequences of this predisposition might be even more manifest in subjects with a shortened dental arch restored with removable dental prosthesis (RDP), because RDPs have been associated with increased incidence of caries and periodontal breakdown [9, 10]. However, a randomised clinical trial revealed no statistically significant difference in frequency of tooth loss after 3 years follow-up among shortened dental arch subjects with and without RDP [11]. Furthermore, quality of life levels of subjects with a shortened dental arch with RDP were found to be almost identical to those of subjects with a shortened dental arch without RDP [12]. In another study, subjects with a shortened dental arch only perceived benefits of RDP from a OHRQoL perspective if anterior teeth replacements are included [6].

To our knowledge, the longest follow-up reports on shortened dental arches are based on a 9-year observational cohort study (3-, 6-, and 9-year observations) [13-15]. It was concluded that shortened dental arches could provide a functional dentition with

long-term occlusal stability [13, 14]. Furthermore, the study reported similar frequencies of signs and symptoms of temporomandibular disorders for shortened dental arches with and without RDP and complete dental arches (CDA) [15]. The present study is evaluating the initial cohort by analyzing 27 to 35 years follow-up data on the basis of information from patient records. The objective of this study was to evaluate the clinical course of shortened dental arches by (1) assessing its longevity; (2) investigating the management of tooth loss; (3) analyzing interventions provided during the follow-up period.

It was hypothesized that shortened dental arches have shorter longevity and receive more restorative interventions and tooth extractions than CDAs. Moreover, it was hypothesized that these effects are more prone in shortened dental arches plus RDP.

Materials and Methods

Data collection

For this study, data from patient records of subjects who participated in a prospective observational cohort study on shortened dental arches (SDA) were used. The subjects from this cohort were regular patients of the Nijmegen Dental School Clinic for check-ups and all necessary dental treatments. The initial cohort, a convenient sample, comprised subjects with shortened dental arches in at least one jaw with three or four posterior occluding pairs (POPs) and intact anterior areas without distal-extension RDP (SDA group; n = 74), subjects with a shortened dental arch extended by RDP (SDA plus RDP group; n = 25) and subjects with CDA (CDA group; n = 72, control group). Teeth replaced by fixed dental prostheses (FDPs) were considered as present; occluding posterior FDP replacements were counted as POPs. Detailed information on the sampling method can be found in a previously published report [13].

For the present study, data were extracted from the available patient records of the subjects of the initial cohort. All restorative interventions provided from the time the subjects had subscribed at the dental school until May 2011, or as long as information was available, were extracted from these records. From the moment dentitions were identified as SDA or SDA plus RDP, the following interventions were considered: direct restorations (fillings), indirect restorations (crowns, in- and onlays), endodontic treatments, and tooth extractions.

To be able to describe the changes in functional status of the dentitions, the total number of lost teeth (excluding third molars) and the number of POPs at baseline and endpoint were determined (Table 3.2). Also, tooth replacements were recorded, including type of replacements (resin-bonded FDP, conventional FDP, partial RDP, and complete dentures) and location in the dental arch.

If subjects became edentulous or if dental records were closed (i.e. subjects decided to stop attending the dental school or died), data recording ceased. Accuracy of the patient records was checked by information of available X-rays and data from the 9-year follow-up observations of the original cohort study.

Statistical analysis

Mean age at baseline of CDA subjects was significantly higher than that of SDA subjects (p -value 0.045). Because comparing groups with a t -test cannot eliminate 'age' as a potential confounding variable, the groups were compared using linear regression analyses with 'age' and 'group' as independent variable. Since the variable 'age' is only used to eliminate confounding from all regression analyses, only the effect (i.e. the difference corrected for age) of the variable 'group' is reported. 'Gender' was also checked for being a potential confounding variable. The group effects with or without gender in the multivariate model were nearly identical, so gender is not a confounder in this study. It appeared that in less than 10% of the analyses 'gender' had an effect and these effects were extremely small compared to the group-effects. Therefore it was decided to not include 'gender' in the models presented. SDA was compared with SDA plus RDP and with CDA. For the analyses presented in Tables 3.3 and 3.4, third molars were taken into account to be able to get insight in the total number of treatments provided in the groups. First, baseline and endpoint status regarding numbers of teeth with direct and indirect restorations and absent teeth were compared. Next, the number of direct and indirect restorations made, endodontic treatments and tooth extractions provided per year were analysed for each group.

Finally, to get insight in which dental regions most interventions were needed, the number of direct restoration provided per tooth per year for the 'anterior region', 'premolar region' and 'molar region' were analysed. For these analyses, in which third molars were excluded, only the time teeth were actually present was taken into account and for the molar region only SDA subjects having molars at baseline were analysed.

The statistical analyses were performed using SPSS 18.0 software.

Results

Sample

Eventually, patient records of 59 subjects of the original cohort (35%) appeared to be retrievable from the database of the dental school. Table 3.1 presents mean age at baseline, gender distribution, and mean time of follow-up of each group (SDA, SDA plus RDP and CDA).

Table 3.1 Number of subjects, mean age at baseline (SD), gender distribution and mean time of follow-up (SD) of the SDA group, SDA plus RDP group and CDA (control) group

	SDA	SDA plus RDP	CDA
N (% of original cohort)	23 (31.1)	13 (52.0)	23 (31.9)
Mean age at baseline (SD)	37.8 (11.2)	40.0 (9.7)	31.7 (8.0)
Male %	21.7	38.5	47.8
Mean time of follow-up	27.4 (7.1)	32.6 (7.3)	35.0 (5.6)

Clinical course

The majority (87%) of the subjects in the SDA group still had an SDA status comprising at least three POPs at the end of the follow-up period (mean: 27.4 years; SD 7.1), despite the loss of 67 teeth in this group during this period (Table 3.2). Three subjects, accountable for 52% of the 67 lost teeth, lost their SDA status; one subject became edentulous and in two subjects shortened dental arches became interrupted dental arches (IDA). In the remaining 20 SDA subjects, FDPs replaced 16 lost teeth, thereby maintaining the SDA status of the subjects. Another 16 lost teeth were not replaced, of which 12 teeth (75%) had no opposing tooth.

At the end of the follow-up period, the functional status of the subjects of the SDA plus RDP group is far more diverse than for subjects of the SDA group. After a mean follow-up time of 32.6 years (SD 7.3) fewer than half of the subjects (46%) still had the status SDA plus RDP. Only three subjects (23%) retained all their POPs. Proportionally, more teeth were lost in this group than in the SDA group (63 teeth in 13 SDA plus RDP subjects vs. 67 teeth in 23 SDA subjects). Generally, the replacement of lost teeth in the SDA plus RDP group was accomplished by (adding teeth to a present) RDP (78% of the lost teeth). Four out of seven subjects who lost their SDA plus RDP status did so

because of further tooth loss: one subject became edentulous and three lost their status because of dental arch interruptions and loss of POPs. The other three subjects lost their SDA plus RDP status because two of them had their RDPs replaced by free-end FDP and one subject ceased wearing the RDP (Table 3.2).

Seventy percent of CDA subjects maintained their status at the end of the follow-up period (35.0 years; SD 5.6). The number of teeth lost was relatively low in this group compared to the SDA group (15 teeth in 23 CDA subjects vs. 67 teeth in 23 SDA subjects). None of the subjects lost more than one POP (Table 3.2).

Interventions

Comparison of SDA with SDA plus RDP

At baseline, there were no statistically significant differences in the mean number of teeth with direct restorations and indirect restorations between the SDA group and the SDA plus RDP group (Table 3.3). Considering absent teeth at baseline, the SDA group had more absent teeth in the upper jaw but fewer absent teeth in the lower jaw compared to the SDA plus RDP group. At the end of follow-up, both the SDA group and the SDA plus RDP group had fewer teeth with direct restorations in the upper jaw than at baseline. This decrease is explained by the increase of number of teeth with indirect restorations (direct restorations were replaced by indirect restorations) and the increase of the number of absent teeth.

The mean numbers of indirect restorations, direct restorations, endodontic treatments, and tooth extractions provided per year did not differ statistically among the SDA group and the SDA plus RDP group (Table 3.4). Focusing on direct restorations provided in the different dental regions also revealed no statistical significant differences between the groups (Table 3.5). In the SDA group, the following RDP-related interventions were provided during the follow-up period: two partial RDPs and one complete denture; for the SDA plus RDP group, this was: 26 replacement partial RDPs (all subjects received 1-4 new/replacement RDPs), 3 additional partial RDPs (in opposite jaw), 24 relinings, 13 repairs, and 9 extensions to add lost teeth to a present RDP and one complete denture.

Table 3.2 Clinical course of SDA, SDA plus RDP and CDA subjects; tooth loss (excluding third molars) and management of tooth loss during follow-up period and dental functional status at end of follow-up

Dental status at baseline	SDA (n = 23)	SDA plus RDP (n = 13)	CDA (n = 23)
Tooth loss and management of tooth loss	<p>Tooth loss: 67 teeth lost in 17 subjects (6 subjects had no tooth loss)</p> <p>Management:</p> <ul style="list-style-type: none"> • 16 teeth not replaced (24%) • 16 teeth by fixed replacement (24%): conventional FDP: 11 resin-bonded FDP: 1 implant: 4 • 35 teeth replaced by RDP (52%): acrylic RDP: 8 teeth (in 2 RDPs) complete denture: 27 teeth (in 1 CD) 	<p>Tooth loss: 63 teeth lost in 12 subjects (1 subject had no tooth loss)</p> <p>Management:</p> <ul style="list-style-type: none"> • 11 teeth not replaced (17%) • 3 teeth by fixed replacement (5%): conventional FDP: 3 • 49 teeth replaced by RDP (78%): metal frame RDP: 27 (in 8 RDPs) complete denture: 22 (in 1 CD) 	<p>Tooth loss: 15 teeth lost in 10 subjects (13 subjects had no tooth loss)</p> <p>Management:</p> <ul style="list-style-type: none"> • 7 teeth not replaced (47%) • 8 teeth by fixed replacement (53%): conventional FDP: 6 resin-bonded FDP: 1 implant: 1 • no RDP replacement (0%)
Dental functional status at end of follow-up and change in number of POPs	<p>Dental status of subjects at end of follow-up:</p> <p>SDA: 20 IDA with RDP: 2 edentulous: 1</p> <p>POPs change in subjects:</p> <ul style="list-style-type: none"> • lost POPs: 16 none: 16 1-2: 4 all: 1 • gained POPs: 2 1: 2 	<p>Dental status of subjects at end of follow-up:</p> <p>SDA with RDP: 6 SDA without RDP: 3 IDA with RDP: 3 edentulous: 1</p> <p>POPs change in subjects:</p> <ul style="list-style-type: none"> • lost POPs: 3 none: 3 1-2: 4 3: 1 all: 3 • gained POPs: 2 1-2: 2 	<p>Dental status of subjects at end of follow-up:</p> <p>CDA: 16 IDA: 3 SDA (slightly): 4</p> <p>POPs change in subjects:</p> <ul style="list-style-type: none"> • lost POPs: 16 none: 16 1: 7 • gained POPs: n.a.

Comparison of SDA with CDA (control)

Although the SDA subjects have, by definition, fewer teeth than CDA subjects, the mean number of teeth with direct restorations and indirect restoration at baseline was not statistically significant different between both groups, except for direct restorations in the lower jaw in the CDA group (Table 3.3). At the end of follow-up, the mean number of teeth with direct and indirect restorations was still not statistically significant different for the lower jaw. For the upper jaw however, the number of direct restorations at the end of follow-up was lower in the SDA group compared to the CDA group (4.00 vs. 6.87) whereas the number of indirect restorations was higher in the SDA group (4.09 vs. 2.00; Table 3.3). The mean numbers of indirect restorations, direct restorations, endodontic treatments and tooth extractions provided per year were only statistically significant different for indirect restorations in upper teeth (0.18 indirect restorations per year in SDA compared to 0.08 per year in CDA; $p=0.008$) (Table 3.4).

For anterior teeth, statistically significant (upper jaw $p=0.025$; lower jaw $p=0.022$) more direct restorations per year were provided in the SDA group than in the CDA group (Table 3.5). There was no statistically significant difference in the number of direct restorations per year in premolars, whilst fewer direct restorations were made per year in molars in the SDA group compared to the CDA group (upper jaw $p=0.021$; lower jaw $p=0.001$) (Table 3.5).

Table 3.3 Number of teeth with direct restorations and indirect restorations, and number of absent teeth for upper and lower jaw for SDA, SDA plus RDP and CDA subjects at baseline and end of follow-up (mean number (SD)). Effect, p-value and 95% CI are corrected for age.

Status per jaw	SDA (n=23)	SDA plus RDP (n=13)	CDA (n=23)	Comparison between SDA and SDA plus RDP		Comparison between SDA and CDA				
				Effect	p-value	Effect	p-value			
Direct restorations										
Upper	baseline	6.00 (3.96)	6.43 (3.32)	-0.48	0.716	[-3.14...2.78]	-0.58	0.602	[-2.81...1.65]	
	endpoint	4.00 (3.22)	3.23 (2.09)	6.87 (3.75)	0.76	0.469	[-1.31...2.83]	-2.97	0.009	[-5.16...-0.77]
Lower	baseline	3.39 (2.39)	2.92 (2.02)	5.83 (2.02)	0.41	0.602	[-1.99...1.17]	-3.70	<0.001	[-5.07...-2.34]
	endpoint	4.52 (2.13)	2.69 (1.80)	4.52 (2.13)	0.93	0.239	[-0.65...2.50]	-1.32	0.064	[-2.72...0.08]
Indirect restorations										
Upper	baseline	0.35 (0.65)	0.08 (0.28)	0.22 (0.67)	0.28	0.160	[-0.12...0.67]	0.07	0.719	[-0.34...0.49]
	endpoint	4.09 (3.01)	3.77 (3.19)	2.00 (2.47)	0.11	0.915	[-2.00...2.22]	2.42	0.006	[0.72...4.12]
Lower	baseline	0.17 (0.58)	0.37 (0.86)	0.13 (0.34)	-0.10	0.682	[-0.58...0.38]	0.03	0.840	[-0.32...0.26]
	endpoint	2.04 (2.48)	2.08 (1.44)	2.52 (2.17)	-0.16	0.833	[-1.67...1.35]	0.19	0.791	[-1.63...1.25]
Absent teeth										
Upper	baseline	4.09 (1.88)	2.62 (2.10)	0.91 (0.95)	1.54	0.032	[0.14...2.94]	2.89	<0.001	[2.00...3.78]
	endpoint	5.22 (2.78)	5.85 (4.10)	1.70 (0.82)	-0.44	0.697	[-2.75...1.86]	3.28	<0.001	[2.01...4.55]
Lower	baseline	5.35 (1.15)	6.23 (0.83)	0.83 (0.94)	-0.92	0.017	[-1.67...-0.17]	4.54	<0.001	[3.88...5.20]
	endpoint	6.04 (2.25)	7.69 (3.23)	1.91 (0.73)	1.58	0.096	[-3.45...0.30]	4.05	<0.001	[3.01...5.09]

Table 3.4 Restorative interventions and tooth extractions provided per year in SDA, SDA plus RDP and CDA subjects for upper and lower jaw (mean number (SD)). Effect, p-value and 95% CI are corrected for age.

Treatment per jaw	SDA (n=23)	SDA plus RDP (n=13)	CDA (n=23)	Comparison between SDA and SDA plus RDP		Comparison between SDA and CDA			
				Effect	p-value	95% CI	Effect	p-value	95% CI
Direct restorations									
Upper	0.72 (0.36)	0.69 (0.41)	0.58 (0.42)	0.04	0.755	[-0.23...0.32]	0.11	0.371	[-0.14...0.36]
Lower	0.38 (0.23)	0.42 (0.23)	0.42 (0.22)	-0.02	0.803	[-0.17...0.13]	-0.07	0.308	[-0.21...0.07]
Indirect restorations									
Upper	0.18 (0.16)	0.19 (0.14)	0.08 (0.09)	-0.02	0.744	[-0.13...0.09]	0.11	0.008	[0.03...0.19]
Lower	0.10 (0.13)	0.09 (0.06)	0.08 (0.06)	0.00	0.914	[-0.07...0.08]	0.04	0.221	[-0.03...0.10]
Endodontic treatments									
Upper	0.05 (0.05)	0.07 (0.08)	0.03 (0.04)	-0.02	0.407	[-0.06...0.03]	0.02	0.154	[-0.01...0.05]
Lower	0.03 (0.04)	0.03 (0.04)	0.02 (0.03)	-0.01	0.699	[-0.03...0.02]	0.01	0.351	[-0.01...0.03]
Tooth extractions									
Upper	0.06 (0.08)	0.12 (0.12)	0.03 (0.03)	-0.05	0.124	[-0.12...0.02]	0.03	0.186	[-0.01...0.06]
Lower	0.05 (0.10)	0.06 (0.10)	0.03 (0.03)	-0.05	0.878	[-0.08...0.07]	0.84	0.610	[-0.04...0.05]

Table 3.5 Direct restorations provided per year in SDA, SDA plus RDP and CDA subjects per tooth for upper and lower jaw (mean number (SD)) (3rd molars excluded). Effect, p-value and 95% CI are corrected for age.

For the molar region only SDA subjects having molars at baseline were included: ^a n= 18; ^b n= 13; ^c n= 8; ^d n= 5

Jaw	Region	SDA (n=23)	SDA plus RDP (n=13)	CDA (n=23)	Comparison SDA – SDA plus RDP		Comparison SDA - CDA	
					effect	p-value	effect	p-value
Upper	Anterior	0.074 (0.049)	0.073 (0.049)	0.034 (0.046)	0.002	0.922	0.034	0.025
	Premolar	0.062 (0.041)	0.038 (0.032)	0.042 (0.029)	0.024	0.077	0.019	0.098
	Molar	0.025 (0.032) ^a	0.036 (0.034) ^b	0.053 (0.036)	-0.013	0.231	-0.025	0.021
Lower	Anterior	0.019 (0.026)	0.031 (0.026)	0.002 (0.003)	-0.010	0.247	0.012	0.022
	Premolar	0.055 (0.035)	0.056 (0.037)	0.045 (0.038)	0.000	0.976	0.014	0.207
	Molar	0.011 (0.020) ^c	0.005 (0.009) ^d	0.056 (0.027)	0.008	0.147	-0.049	0.001

[95% CI]

[0.005...0.064]

[0.004...0.041]

[-0.047...0.004]

[0.002...0.022]

[-0.008...0.037]

[-0.064...0.034]

Discussion

This observational cohort study demonstrated that shortened dental arches could be preserved for periods of 27 years and over. On dentition level the number of restorative interventions provided per year was not significantly different among the groups, except that SDA received significantly more indirect restorations in the upper jaw than CDA. Partially this is due to the high number of abutment crowns needed for the high number of FDPs provided in SDA subjects. This indicates that on dentition level the cost of restorative treatment in a shortened dental arch is at least as high as the costs of restorative treatment in a CDA. However, on tooth level it was found that in the SDA group compared to the CDA group more direct restorations were provided per tooth per year, except for molars. A plausible explanation for these higher numbers of direct restorations per tooth per year in shortened dental arches is that a predisposition to dental diseases in this group, that caused the loss of molars in the first place, continues to have its effect on the remaining dentition. In course of time this will necessitate additional treatment since new carious lesions develop. However, the reasons for restorative treatment were often not available from the records.

Besides the initial restoration of carious lesions, fillings are also made to replace previous restorations for reasons such as fracture of the filling or secondary caries. A review of 10 surveys including 32.777 direct restorations revealed that more than 50% of the provided restorations were replacements of previous restorations [16]. Therefore, it is assumable that considerable numbers of direct restorations provided in this cohort were replacement restorations. Hence, the high numbers of restorations provided per year per tooth in SDA subjects (Table 3.5) can probably partly be explained by the fact that SDA subjects already had relatively higher restoration levels (i.e. comparable numbers of teeth with restorations but in total significantly fewer teeth) at baseline than CDA subjects (Table 3.3). The only exception was the number of teeth with direct restorations in the lower jaw (5.83 in the CDA group vs. 3.39 in the SDA group), which can be explained by the large difference in numbers of teeth present among the groups (0.83 teeth absent in CDAs vs. 5.35 in SDA).

Another explanation might be that in shortened dental arches fewer teeth have to bear the loads that occur during chewing. Consequently, increased loading of fewer teeth in shortened dental arches compared to CDAs possibly results in a higher failure rate of fillings in shortened dental arches. However, a study on masticatory performance showed that in shortened dental arches significantly lower occlusal forces could be

measured than in complete dental arches [2]. In line with this, it is feasible that the higher number of direct restorations made in shortened dental arches is not due to overloading and subsequent failure of fillings.

For the present study, information from patient records from the dental school was used. If subjects incidentally visited a general dentist outside the dental school for treatment it is likely that relevant information is missing. In the Netherlands however, where this investigation was conducted, patients are generally loyal to their dentist and only seldom switch temporarily. Therefore, we trust that the information in the dental school records is reasonably complete. However, to confirm the accuracy of the records, the data were compared with available X-rays and the investigation forms of the original cohort study.

The small sample size and selected group of dental school patients might limit external validity of this study, e.g. due to stricter maintenance protocols applied to these patients. On the other hand, we consider the quality of the data satisfactory for conclusive outcomes. Sixty-five percent of the dental records of the subjects of the original cohort were not retrievable, mainly of subjects who stopped attending the dental school. According to the Dutch legislation, patient files must be kept at least for 10 years from the moment patients unsubscribe. Fortunately, most files were kept longer, but still a reasonable number of archived files were destroyed. Probably most of these were destroyed at the time that the Nijmegen Dental School changed from paper to electronic patient files in 2003. The destruction of archived records seems to be rather arbitrary and as a result selection bias is considered absent or small.

The number of female subjects was proportionally high for the SDA group and the SDA plus RDP group, whereas gender distribution for the CDA group was even (Table 3.1). This high percentage female subjects is a reflection of the dental school patient population. The CDA subjects, as being a control group, were selected by purpose sampling aiming at equal gender proportions. However, analyses did not reveal gender effects and therefore correction for gender was not considered necessary.

Previous longitudinal studies on tooth loss reported mean numbers of 0.03 to 0.24 teeth lost per year [17, 18]. This is in accordance with incidence of tooth loss found in the present study; incidence varied from 0.03 to 0.12 teeth per year depending on location and group, with the lowest incidence for the lower jaw in the CDA group and highest incidence for the upper jaw in the SDA plus RDP group. In the majority of SDA subjects in the present study however, tooth loss did not lead to loss of their SDA status:

a considerable number of lost teeth were molars without opposing tooth whilst lost teeth causing interruption of the dental arch were replaced by FDPs, by what means the SDA status was maintained. However, especially as incidence of tooth loss has been reported to increase with age, further tooth loss can be expected for this meanwhile aged cohort, which can endanger the functionality of the dentitions [18, 19].

It is striking that three of the 23 SDA subjects (these were also the subjects who lost their SDA status) were accountable for 52% of the lost teeth. In contrast to this, 6 SDA subjects did not lose any tooth at all during the follow-up period. Apparently in these subjects the predisposition to dental diseases, as argued above, could be stopped or at least substantially decreased. To what extent and how risk factors for tooth loss exactly continue to have their effect in SDA subjects, is a phenomenon that needs further investigation.

At the start of the study it was hypothesized that adverse effects are more prone in SDA plus RDP subjects than in SDA subjects. However, it appeared that the number of tooth extractions per year was not statistically significant different. This is in accordance with the outcomes of a randomised clinical trial on tooth loss in shortened dental arches with or without RDP; Kaplan-Meier survival rates were not statistically significant different between the two groups in a 3-year follow-up period [11]. Although the incidence of tooth loss is not significantly different between groups, 7 out of 13 SDA plus RDP subjects lost their SDA plus RDP status during the follow-up period whilst only 3 out of 23 SDA subjects lost their SDA status. This is also reflected in the loss of POPs; 62% of the SDA plus RDP subjects lost one or more POP vs. 22% of the SDA subjects. However, not all subjects lost their SDA plus RDP status due to further tooth loss; three subjects lost this status because they stopped wearing their RDP and two of them actually gained POPs by having their RDPs replaced by free-end FDPs.

The number of restorative interventions for the SDA plus RDP group provided per year during the follow-up period was not significantly different indicating that the costs at dentition level are the same as in SDAs. When the costs related to RDP are taken into account it can be concluded that the total costs in the SDA plus RDP group was higher whereas the longevity appeared to be lower compared to shortened dental arches without RDP. Additionally, apart from costs, every new RDP or RDP adjustment can bring discomfort and will make a considerable appeal on the adaptability of a patient. Moreover, it is questionable whether SDA patients actually benefit from RDP. As stated before, RDPs seem to contribute to OHRQoL only if anterior teeth replacements are

included [6]. Furthermore, Aras et al. showed that RDPs in shortened dental arches did not improve masticatory performance [2] and McKenna et al. [20] showed that both prosthetic rehabilitation to a functional dentition as well as full rehabilitation including RDP, did not improve the nutritional status as reflected in hematological markers. Several studies, including the present study, showed that RDPs often even have an adverse effect [10, 21-23]. In a randomised clinical trial on caries incidence following restoration of shortened lower dental arches in an elderly sample of patients, it was found that 2 years after restoration, there was a significantly greater incidence of new and recurrent caries lesions in subjects restored with RDPs compared with cantilever resin-bonded bridges [22]. In the same sample of elderly, it was found that subjects considered restoration with cantilever resin-bonded bridges more comfortable than restoration with RDP [23]. Also, a higher maintenance frequency for RDPs compared to resin-bonded FDPs in shortened lower dental arches was reported [10]. In summary, it can be stated that replacement of absent posterior teeth by a free-end RDP in a shortened dental arch is not recommendable; fixed appliances (cantilever (resin-bonded) FDP or implant supported FDP) might be preferable alternatives.

Recently, the body of evidence on the SDA concept was assessed by means of the Grading of Recommendation Assessment and Evaluation (GRADE) [24]. The conclusion of this assessment was that the quality of the evidence for recommendation of the management of shortened dental arches is low because of the lack of evidence provided by randomised clinical trials [24]. However, conducting well-designed randomised clinical trials may be not feasible because of concerns of ethical and practical nature. Although the present study is not a randomised clinical trial, the strength of the present study is that it is a long-term clinical observational cohort study that provides valuable, long-term clinical data on the clinical course of shortened dental arches.

Conclusions and clinical relevance

This study shows that shortened dental arches can last for 27 years and over. On dentition level, the number of treatments provided is comparable with complete dentitions. Herewith, this study contributes to the body of evidence that the SDA concept is a cost-effective approach. Moreover, replacement of absent posterior teeth by free-end RDP in shortened dental arches is not recommendable since RDP seems to be associated with a less favourable clinical course.

References

1. Kanno T, Carlsson GE. A review of the shortened dental arch concept focusing on the work by the Käyser/Nijmegen group. *J Oral Rehabil.* 2006;33:850-62.
2. Aras K, Hasanreisoglu U, Shinogaya T. Masticatory performance, maximum occlusal force, and occlusal contact area in patients with bilaterally missing molars and distal extension removable partial dentures. *Int J Prosthodont.* 2009;22:204-9.
3. Gerritsen AE, Sarita P, Witter DJ, Kreulen CM, Mulder J, Creugers NHJ. Esthetic perception of missing teeth among a group of Tanzanian adults. *Int J Prosthodont.* 2008;21:169-73.
4. Gotfredsen K, Walls AW. What dentition assures oral function? *Clin Oral Implants Res.* 2007;18 Suppl 3:34-45.
5. Witter DJ, Van Elteren P, Käyser AF, Van Rossum GM. Oral comfort in shortened dental arches. *J Oral Rehabil.* 1990;17:137-43.
6. Armellini DB, Heydecke G, Witter DJ, Creugers NHJ. Effect of removable partial dentures on oral health-related quality of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont.* 2008;21:524-30.
7. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont.* 2008;21:72-4.
8. Montero J, Bravo M, Hernandez LA, Dib A. Effect of arch length on the functional well-being of dentate adults. *J Oral Rehabil.* 2009;36:338-45.
9. Budtz-Jørgensen E, Isidor F. A 5-year longitudinal study of cantilevered fixed partial dentures compared with removable partial dentures in a geriatric population. *J Prosthet Dent.* 1990;64:42-7.
10. Thomason JM, Moynihan PJ, Steen N, Jepson NJ. Time to survival for the restoration of the shortened lower dental arch. *J Dent Res.* 2007;86:646-50.
11. Walter MH, Weber A, Marré B, Gitt I, Gerss J, Hannak W, et al. The randomized shortened dental arch study: tooth loss. *J Dent Res.* 2010;89:818-22.
12. Kuboki T, Okamoto S, Suzuki H, Kanyama M, Arakawa H, Sonoyama W, et al. Quality of life assessment of bone-anchored fixed partial denture patients with unilateral mandibular distal-extension edentulism. *J Prosthet Dent.* 1999;82:182-7.
13. Witter DJ, Creugers NHJ, Kreulen CM, de Haan AF. Occlusal stability in shortened dental arches. *J Dent Res.* 2001;80:432-6.
14. Witter DJ, Kreulen CM, Mulder J, Creugers NHJ. Signs and symptoms related to temporomandibular disorders--Follow-up of subjects with shortened and complete dental arches. *J Dent.* 2007;35:521-7.
15. Creugers NHJ, Witter DJ, Van 't Spijker A, Gerritsen AE, Kreulen CM. Occlusion and Temporomandibular Function among Subjects with Mandibular Distal Extension Removable Partial Dentures. *Int J Dent.* 2010;2010:807850.
16. Deligeorgi V, Mjör IA, Wilson NH. An overview of reasons for the placement and replacement of restorations. *Prim Dent Care.* 2001;8:5-11.
17. Haugejorden O, Klock KS, Trovik TA. Incidence and predictors of self-reported tooth loss in a representative sample of Norwegian adults. *Community Dent Oral Epidemiol.* 2003;31:261-8.
18. Müller F, Naharro M, Carlsson GE. What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe? *Clin Oral Implants Res.* 2007;18 Suppl 3:2-14.
19. Fure S, Zickert I. Incidence of tooth loss and dental caries in 60-, 70- and 80-year-old Swedish individuals. *Community Dent Oral Epidemiol.* 1997;25:137-42.
20. McKenna G, Allen PF, Flynn A, O'Mahony D, Damata C, Cronin M, et al. Impact of tooth replacement strategies on the nutritional status of partially-dentate elders. *Gerodontology.* 2011; e883-90. doi:10.1111/j.1741-2358.2011.00579.x.
21. do Amaral BA, Barreto AO, Gomes Seabra E, Roncalli AG, da Fonte Porto Carreiro A, de Almeida EO. A clinical follow-up study of the periodontal conditions of RPD abutment and non-abutment teeth. *J Oral Rehabil.* 2010;37:545-52.
22. Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J.* 2001;191:140-4.

23. Jepson N, Allen F, Moynihan P, Kelly P, Thomason M. Patient satisfaction following restoration of shortened mandibular dental arches in a randomized controlled trial. *Int J Prosthodont.* 2003;16:409-14.

24. Faggion CM, Jr. The shortened dental arch revisited: from evidence to recommendations by the use of the GRADE approach. *J Oral Rehabil.* 2011;38:940-9.

Chapter 4

Increased risk for premolar tooth loss in shortened dental arches

Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. Increased risk for premolar tooth loss in shortened dental arches. *Journal of Dentistry*. 2013;41:726-31.

Abstract

Aim

To assess sustainability of shortened dental arches (SDA) by determining time to 'first restorative intervention' of teeth and time to 'tooth loss' and comparing these outcomes with complete dental arches (CDA) and SDAs plus removable dental prostheses (RDP).

Methods

Data (follow-up time ranged from 27.4 (SD 7.1) to 35.0 (SD 5.6) years; max. follow-up: 45.8 years) from patient records of 59 subjects (23 SDA, 23 CDA, and 13 SDA plus RDP) participating in a prospective cohort study on SDAs were analysed. Group effects on survival were analysed using Cox regression models; where appropriate Kaplan-Meier analyses were done.

Results

Compared to SDA subjects, CDA subjects had a lower risk to receive a first restorative intervention in anterior teeth (HR = 0.377; 95% CI [0.205...0.695]) and premolars (HR = 0.470; 95% CI [0.226...0.977]). CDA subjects had a lower risk to lose premolars compared to SDA subjects (HR = 0.130; 95% CI [0.053...0.319]). Risk for 'first restorative intervention' and for 'tooth loss' did not significantly differ between SDA with and without RDP.

Conclusions

SDA subjects had an increased risk to lose premolars and to receive a first-time restoration in anterior teeth and premolars compared to CDA subjects. SDA subjects with RDP had no increased risk to receive a first restorative intervention or for tooth loss compared to SDA without RDP.

Background

Over the last decades, a trend of an increasing number of subjects that retain more teeth during life is visible, at least in Europe [1]. However, in many situations the preservation of a complete natural dentition is biologically not achievable and/or not affordable. Consequently, many dentate subjects present with reduced dentitions that possibly need tooth replacements. A well-described, specific type of reduced dentitions is the so-called shortened dental arch. A shortened dental arch is defined as a reduced dentition with an intact anterior region but a reduced number of occluding pairs of posterior teeth starting from posteriorly. Systematic reviews addressing the shortened dental arch concept demonstrated acceptable functionality and stability [2-4], whilst clinical studies do not demonstrate distinct advantages of restoring shortened dental arches with removable dental prostheses (RDP) [5-12].

Tooth loss is often the final consequence of dental diseases; therefore it can be stated that subjects with a shortened dental arch have a history of dental disease. It is reasonable to assume that a predisposition to dental diseases - such as in subjects with shortened dental arches - is not affecting exclusively the most posterior teeth, and will not disappear by extracting these teeth. Following this assumption, subjects with shortened dental arches would abidingly be at risk to lose remaining teeth [13]. On the other hand, there is abundant literature providing evidence that molars are at higher risk for tooth loss than other tooth types [14-17], so it can be argued whether in shortened dental arches only teeth with 'low' risk for tooth loss remain.

Tooth loss endangers sustainability of the dentition. It is often the outcome of a complex history, which is not only influenced by dental diseases or other detrimental processes (i.e. tooth wear) and its sequelae, but also by the decisions taken by dentists when evaluating possible risk factors for rendering successful therapy [18]. Cumulative damage of teeth by subsequent restorative interventions during many years might lead to a dubious prognosis and extraction might be appropriate instead of further (expensive) restorative treatment with a doubtful long-term result [15, 18-20]. However, if new tooth defects resulting from dental disease or other detrimental processes do not develop and tooth loss does not occur, it can be considered that a patient is at a state of low risk, which endorses sustainability of the dentition. In a shortened dental arch, continued tooth loss endangers not only the sustainability of the dentition as such, but due to its yet reduced number of teeth also its functionality. Removable dental prostheses (RDPs) are often applied to compensate for loss of functionality of reduced dentitions. However, the

sustainability of dentitions restored with RDP might be even at higher risk since wearing an RDP is associated with caries development, periodontal breakdown and tooth loss [8, 10, 21-23].

The aim of this study was to analyse the sustainability of shortened dental arches by considering two clinical endpoints: (1) time to the first restorative intervention of teeth, and (2) time to tooth loss. Shortened dental arch subjects (SDA group) were compared with subjects with complete dental arches (CDA group). Additionally, the subjects with shortened dental arch were compared with shortened dental arch subjects wearing removable dental prostheses (SDA plus RDP group). We hypothesized that in shortened dental arch subjects hazard probabilities for 'first restorative intervention' and 'tooth loss' are higher compared to CDA subjects and lower compared to SDA plus RDP subjects.

Materials and Methods

Data collection

Data from patient records of subjects participating in a prospective observational cohort study on shortened dental arches (SDA) were analysed. Detailed information on sampling method has been published previously [24]. Subjects from this study were attending the Nijmegen Dental School Clinic for their dental check-ups and treatments at the time (1981-1985) they entered the cohort study. This convenient sample included SDA subjects without free-end RDPs (SDA group; n = 74) and with free-end RDPs replacing absent molars (SDA plus RDP group; n = 25), and a control of subjects with complete dental arches (CDA group; n = 72). All SDA subjects (with and without RDP) had intact anterior areas and 3-4 posterior occluding pairs (POPs). The majority of the SDA subjects (94%) had one or more non-functional (i.e. not occluding) molars.

The criterion for inclusion of subjects of the original cohort study in the present analysis was the availability of a patient record at time of the analyses. Data were extracted from patient records that were administered following the Nijmegen Dental School protocol. If applicable, information recorded prior to the time the subject entered the cohort study was also used in the analyses. As an example, the subject with the longest follow-up time was a lady with an SDA who subscribed as a 28-year-old to the dental school in 1965, entered the cohort study in 1983, and is until to date a regular attender of the dental school. By including this information we were able to include follow-up data up to 45.8 years.

Presence and restorative status at baseline was recorded per tooth. Baseline was set at the date (1) a subject subscribed at the dental school (either having an SDA status or a CDA), or (2) tooth extraction resulted in a shortened dental arch status. During the follow-up period data on restorative interventions and tooth loss were extracted from retrievable patient records until May 2011 or until the most recent date that information was added to the record. Available x-rays were used to check the accuracy of the data. At the end of the follow-up period the principal investigator clinically investigated the majority of the 37 subjects still attending the Dental School; 5 out of these subjects were not available. The ethical committee of the Radboud University Medical Centre permitted the conduct of this study by decision cmo-nr 2010/316.

Statistical analysis

Two clinical endpoints were defined in the survival analysis comparing the groups: (1) 'first restorative intervention' (in anterior teeth and premolars that never received dental restorative treatment before), and (2) 'tooth loss' of anterior teeth and premolars. Molars were not included in the analyses. Cumulative survivals are presented by Kaplan-Meier survival curves.

Statistical package R, version 2.13.1, was used for statistical analysis [25]. To test the hypotheses, the SDA group was assigned to be the reference group. To analyse effects of the groups on survival, a Cox regression model was applied with group as independent variable and corrected for age. This was done for time to first restorative intervention and time to tooth loss. Data on tooth level cannot be considered independent because multiple teeth per subject were included. Therefore, the Cox model was extended with a gamma frailty term to model this clustering of data [26]. In cases where the proportional hazard assumption was not fulfilled, Kaplan-Meier analyses were done to compare the three groups with the extension as described by Ying and Wei to correct for clustered data [27, 28].

Results

Sample

Patient records of 59 subjects of the original cohorts (35%) appeared to be retrievable. Of these records, 22 (37%) were closed on a date before May 2011; of 37 records (63%) information was available up to the end of the study period. As a result, mean follow-up

time of subjects in the three groups ranged from 27.4 (SD 7.1) up to 35.0 (SD 5.6) years (Table 4.1).

Table 4.1 Number of subjects, mean age at baseline (SD), gender distribution, mean time of follow-up (SD), and mean number of teeth (SD) of SDA, CDA, and SDA plus RDP

	SDA	CDA	SDA plus RDP
N (% of original cohort)	23 (31.1)	23 (31.9)	13 (52.0)
Mean age at baseline (SD)	37.8 (11.2)	31.7 (8.0)	40.0 (9.7)
Male %	21.7	47.8	38.5
Mean time of follow-up (years)	27.4 (7.1)	35.0 (5.6)	32.6 (7.3)
Anterior teeth			
Mean no. of teeth present	12.0 (0.0)	12.0 (0.0)	12.0 (0.0)
Mean no. of teeth unrestored	7.0 (3.4)	10.6 (0.6)	7.1 (3.5)
Premolars			
Mean no. of teeth present	7.7 (0.5)	8.0 (0.0)	6.8 (0.6)
Mean no. of teeth unrestored	1.9 (1.7)	3.7 (2.8)	1.1 (1.8)
Molars			
Mean no. of teeth present	2.3 (1.3)	8.0 (0.0)	3.5 (1.1)
Mean no. of teeth unrestored	0.2 (0.4)	1.1 (2.0)	0.5 (1.0)

Time to 'first restorative intervention'

Times to 'first restorative intervention' in anterior teeth and premolars were highest in CDA (Figs 4.1 and 4.2); hazard ratios for having 'first restorative intervention' for these teeth in CDA were statistically significant lower than for teeth in SDA (Table 4.2). There were no statistically significant differences between SDA and SDA plus RDP regarding the risks for 'first restorative intervention' of anterior teeth and premolars ($p = 0.496$ respectively 0.627).

Time to 'tooth loss'

Survival of anterior teeth was not statistically significant amongst groups (Fig. 4.3 and Table 4.2). Survival of premolars was significantly higher in CDA (HR: 0.13; $p < 0.001$) whereas no significant difference was found between SDA and SDA plus RDP (HR: 1.21; $p = 0.587$) (Fig. 4.4 and Table 4.2).

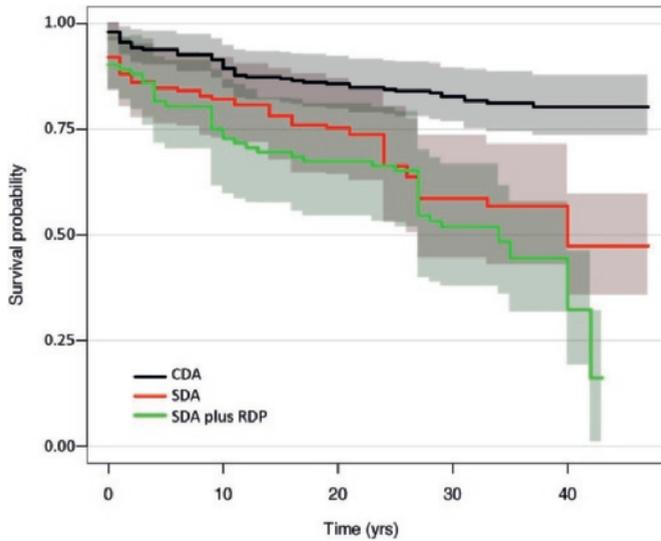


Figure 4.1 Time to 'first restorative intervention' in anterior teeth in SDA (92 out of 151 teeth unrestored at end of follow-up), CDA (198 out of 244 teeth unrestored at end of follow-up) and SDA plus RDP (41 out of 92 teeth unrestored at end of follow-up). Coloured areas indicate 95% confidence intervals.

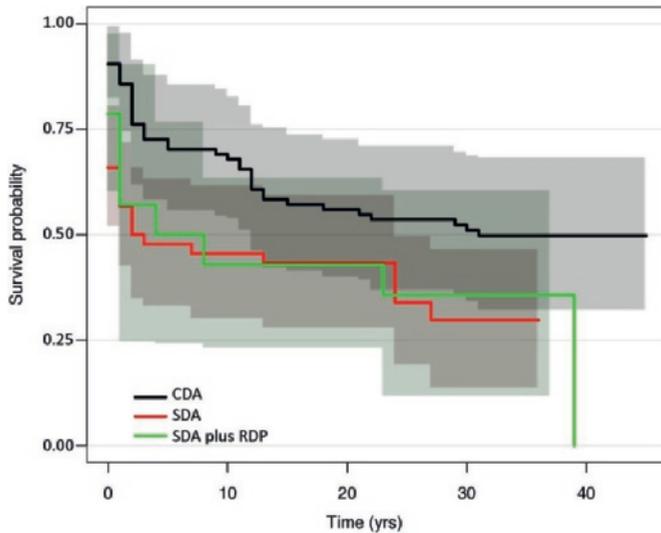


Figure 4.2 Time to 'first restorative intervention' in premolars in SDA (15 out of 44 teeth unrestored at end of follow-up), CDA (42 out of 84 teeth unrestored at end of follow-up) and SDA plus RDP (4 out of 14 unrestored at end of follow-up). Coloured areas indicate 95% confidence intervals.

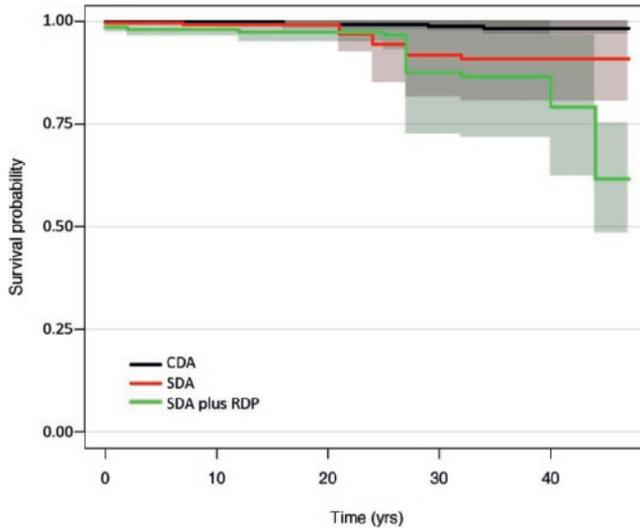


Figure 4.3 Cumulative survival of anterior teeth in SDA (258 out of 276 teeth present at end of the follow-up), CDA (272 out of 276 teeth present at end of the follow-up) and SDA plus RDP (133 out of 156 teeth present at end of the follow-up). Coloured areas indicate 95% confidence intervals.

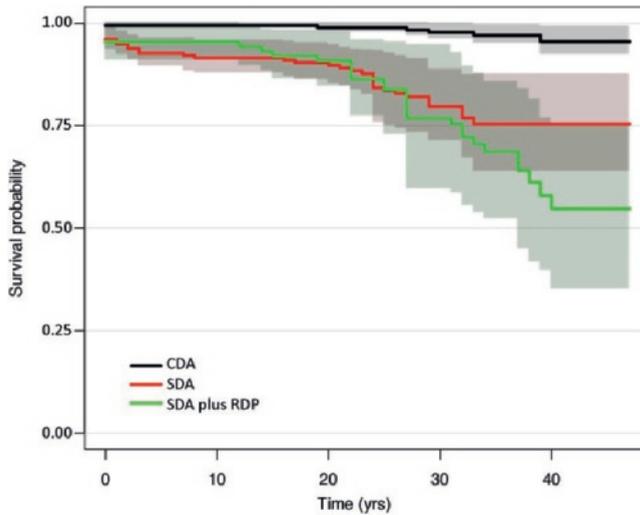


Figure 4.4 Cumulative survival of premolars in SDA (144 out of 178 premolars present at end of the follow-up), CDA (178 out of 184 premolars present at end of the follow-up) and SDA plus RDP (69 out of 88 premolars present at end of the follow-up). Coloured areas indicate 95% confidence intervals.

Table 4.2 Hazard ratios (HRs) to reach endpoints 'first restorative intervention' and 'tooth loss' for anterior teeth and premolars, adjusted for age. SDA is reference group for CDA and SDA plus RDP

	HR	95% CI of HR	p-value
First restorative intervention			
Anterior teeth			
CDA	0.377	[0.205...0.695]	0.002
SDA plus RDP	1.244	[0.663...2.333]	0.496
Age	1.019	[0.982...1.048]	0.167
Premolars			
CDA	0.470	[0.226...0.977]	0.043
SDA plus RDP	1.151	[0.508...3.081]	0.627
Age	0.963	[0.930...0.996]	0.029
Tooth loss			
Anterior teeth			
CDA	0.217	[0.032...1.465]	0.117
SDA plus RDP	1.619	[0.289...9.055]	0.583
Age	1.098	[1.025...1.177]	0.008
Premolars			
CDA	0.130	[0.053...0.319]	<0.001
SDA plus RDP	1.213	[0.605...2.432]	0.587
Age	1.062	[1.030...1.095]	<0.001

Discussion

We conducted this cohort study to investigate long-term sustainability of shortened dental arches. Initially, a prospective trial was designed to investigate the functionality and stability of shortened dental arches [6, 11, 29]. After the 9-year evaluation it was decided to stop the study. However, the Nijmegen Dental School Clinic offered the subjects continued oral care and a substantial number continued attending the dental school. Recently we formulated new research questions to be answered by analysing long-term follow-up data of the original cohort. As a result, the present analyses were based on the original prospective data extended with 'new' retrospective data from patient records. Although part of the results was based on patient records, we consider this relative weakness of the study design compensated by the large number of subsequent recordings during a long follow-up period, which we consider the strength of this study.

The small sample size and selected group of dental school patients might limit external validity of this study, e.g. due to stricter maintenance protocols applied to these patients. The common problem of loss to follow-up of participants in long-term follow-up studies was also seen in the present study. The dental histories did not provide hints pointing at bias due to selective cancellation of subscription of subjects to the dental school. In addition, this study had to cope with loss of records. Occasionally subjects that cancelled their subscription requested their dental records, which led to loss of information. Also clearance of archived records - which happened in a number of cases - seems to have been rather arbitrary and not patient dependent and is therefore considered random. In summary, we consider the quality of the data satisfactory for conclusive outcomes.

This study showed that in a period of 27 years and over, subjects with shortened dental arches have an increased risk for premolar tooth loss compared to subjects with complete dental arches. It can be argued whether this premolar loss is an eventual result of accumulating damage to teeth inflicted by a sequel of re-restoration. It may also be the result of the continued predisposition for dental diseases that is supposed to have led to the shortened dental arch status. The relative high risk for first time restorative interventions in unrestored teeth in subjects with shortened dental arches points in the direction of the latter as there seems to be a continuing deteriorating process resulting in fewer sound and non-restored anterior teeth and premolars. Apparently, in subjects with shortened dental arches risks that initially affected the molar region subsist. It appeared that the reasons for intervention were insufficiently specified, especially in the early notes in the records. Therefore, it was not possible to assess the exact reason for first time restorative intervention.

The role of periodontal disease could not be assessed sufficiently reliable for conclusive analysis. Nevertheless, the 9-year follow-up showed that there were some significant but small differences in periodontal support (as assessed from standardized x-rays and expressed by relative bone height) between the groups, but that these differences were constant over time [10]. This finding did not point at differences amongst the groups with respect to having increased risk for (the development of) periodontal disease. Other reports on periodontal conditions of shortened dental arches revealed significant difference between shortened dental arches with and without RDP after a 5-year period [11, 30]. However, the randomised controlled trail described in these reports did not include complete dentitions and therefore could not determine

relative risk for shortened dental arches compared to complete dental arches. In summary, despite the lack of precise information regarding caries or periodontal disease progress, a continued predisposition for dental diseases in shortened dental arches seems to be manifest. Following this reasoning, subjects with shortened dental arches can be discerned as enduring at-risk patients. It is therefore recommended that shortened dental arch subjects should receive continuous and intensive care to prevent the loss of teeth with strategic importance. However, in spite of the increased risk for premolar tooth loss, the majority of the SDA subjects (20 out of the 23) maintained their SDA status after a follow-up of 27 years and over, because many of the lost teeth were replaced by FDPs [31].

The hypothesis that shortened dental arch subjects have increased risk for having 'first restorative intervention' and for 'tooth loss' compared to CDA is accepted except for loss of anterior teeth. To our knowledge this is the first study comparing shortened dental arches with complete dental arches with respect to their sustainability. Our finding that SDA subjects had increased risk for loss of premolars (compared to CDA) is not in line with two population based follow-up studies revealing that tooth loss was not associated with number of teeth present at baseline [15, 32].

In addition, it should be noted that the difference in average age the SDA and the CDA groups (37.8 versus 31.7) might cause bias. Although the outcomes have been corrected for age, there still might be an effect from differences in the approach of dental disease management and used restorative materials during the adolescent years of the subjects: youngster were differently treated in, for instance, the mid 1950s than in the mid 1960s. As a result it is expected that subjects in the CDA group may have had initially a lower risk history for dental disease because of the different era in which they grew up.

The hypothesis that SDA plus RDP subjects have higher risk for having 'first restorative intervention' and tooth loss than SDA subjects without RDP is weakly supported by the data. In all comparisons between SDA plus RDP and SDA the hazard ratio is larger than 1, however, the effect is always far from statistical significance. Considering the wide confidence intervals for these hazard ratios, the comparison between the two SDA groups is hampered by a relatively low power.

It is tempting to compare the first restorative intervention outcomes of this study with caries development in other clinical studies investigating caries incidence in SDA subjects wearing RDP [11, 12, 23]. However, it should be noted that first restorative

intervention must be considered as an overestimation of caries incidence in the present study, because also other reasons were mentioned (if mentioned) in the records such as the treatment of tooth fracture or tooth wear. Considering an overestimation for caries incidence, comparison with the study of Jepson et al. (2001) shows a much higher caries incidence in RDP wearers in the latter [12]. A study of Budzt-Jørgensen (1990), which had a comparable study population to the Jepson study [12], shows a similar picture [23]. A possible reason for this difference might be the older mean age of the subjects at baseline in the studies of Jepson and Budzt-Jørgensen compared to the present study (approx. 25 years difference) which might be accompanied with limited self-care. Moreover, the relative strict maintenance protocols applied to all participants of the present study might be a reason for better caries management and therefore a lower caries prevalence compared to the Jepson and the Budzt-Jørgensen studies [12, 23].

Regarding tooth loss, the findings are in line with the 5-year report of another randomised clinical trial that reported a non-significant difference between shortened dental arches restored with and without RDP [13].

Conclusions

Within the limitations of the study, it is concluded that subjects with a shortened dental arch had an increased risk to lose premolar teeth. For subjects with a shortened dental arch the risk to receive a first-time restoration was increased for both premolars and anterior teeth. This study did not provide evidence that teeth in SDA with RDP have increased risk to receive a first time restoration. SDA with RDP showed no increased risk for tooth loss compared to SDA without RDP.

References

1. Müller F, Naharro M, Carlsson GE. What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe? *Clin Oral Implants Res.* 2007;18 (Suppl 3):2-14.
2. Fueki K, Yoshida E, Igarashi Y. A systematic review of prosthetic restoration in patients with shortened dental arches. *Japanese Dental Science Review.* 2011;47:167-74.
3. Gotfredsen K, Walls AW. What dentition assures oral function? *Clin Oral Implants Res.* 2007;18 (Suppl 3):34-45.
4. Kanno T, Carlsson GE. A review of the shortened dental arch concept focusing on the work by the Käyser/Nijmegen group. *J Oral Rehabil.* 2006;33:850-62.
5. Armellini DB, Heydecke G, Witter DJ, Creugers NHJ. Effect of removable partial dentures on oral health-related quality of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont.* 2008;21:524-30.
6. Creugers NHJ, Witter DJ, Van 't Spijker A, Gerritsen AE, Kreulen CM. Occlusion and Temporomandibular Function among Subjects with Mandibular Distal Extension Removable Partial Dentures. *Int J Dent.* 2010;2010:807850.
7. Jepson N, Allen F, Moynihan P, Kelly P, Thomason M. Patient satisfaction following restoration of shortened mandibular dental arches in a randomized controlled trial. *Int J Prosthodont.* 2003;16:409-14.
8. McKenna G, Allen PF, Flynn A, O'Mahony D, DaMata C, Cronin M, et al. Impact of tooth replacement strategies on the nutritional status of partially-dentate elders. *Gerodontology.* 2012;29:e883-90.
9. Thomason JM, Moynihan PJ, Steen N, Jepson NJ. Time to survival for the restoration of the shortened lower dental arch. *J Dent Res.* 2007;86:646-50.
10. Witter DJ, Creugers NHJ, Kreulen CM, de Haan AF. Occlusal stability in shortened dental arches. *J Dent Res.* 2001;80:432-6.
11. Wolfart S, Marré B, Wöstmann B, Kern M, Mundt T, Luthardt RG, et al. The randomized shortened dental arch study: 5-year maintenance. *J Dent Res.* 2012;91:65S-71S.
12. Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J.* 2001;191:140-4.
13. Walter MH, Hannak W, Kern M, Mundt T, Gernet W, Weber A, et al. The randomized shortened dental arch study: tooth loss over five years. *Clin Oral Investig.* 2013;17:877-86.
14. Axelsson P, Lindhe J. The effect of a plaque control program on gingivitis and dental caries in schoolchildren. *J Dent Res.* 1977;56 Spec No:C142-8.
15. Bahrami G, Vaeth M, Kirkevang LL, Wenzel A, Isidor F. Risk factors for tooth loss in an adult population: a radiographic study. *J Clin Periodontol.* 2008;35:1059-65.
16. Fure S. Ten-year incidence of tooth loss and dental caries in elderly Swedish individuals. *Caries Res.* 2003;37:462-9.
17. Paulander J, Axelsson P, Lindhe J, Wennström J. Intra-oral pattern of tooth and periodontal bone loss between the age of 50 and 60 years. A longitudinal prospective study. *Acta Odontol Scand.* 2004;62:214-22.
18. Holm-Pedersen P, Lang NP, Müller F. What are the longevities of teeth and oral implants? *Clin Oral Implants Res.* 2007;18 (Suppl 3):15-9.
19. Deligeorgi V, Mjor IA, Wilson NH. An overview of reasons for the placement and replacement of restorations. *Prim Dent Care.* 2001;8:5-11.
20. Lucarotti PS, Holder RL, Burke FJ. Outcome of direct restorations placed within the general dental services in England and Wales (Part 1): variation by type of restoration and re-intervention. *J Dent.* 2005;33:805-15.
21. Kern M, Wagner B. Periodontal findings in patients 10 years after insertion of removable partial dentures. *J Oral Rehabil.* 2001;28:991-7.
22. Preshaw PM, Walls AW, Jakubovics NS, Moynihan PJ, Jepson NJ, Loewy Z. Association of removable partial denture use with oral and systemic health. *J Dent.* 2011;39:711-9.
23. Budtz-Jørgensen E, Isidor F. A 5-year longitudinal study of cantilevered fixed partial dentures compared with removable partial dentures in a geriatric population. *J Prosthet Dent.* 1990;64:42-7.
24. Witter DJ, van Elteren P, Käyser AF. Migration of teeth in shortened dental arches. *J Oral Rehabil.* 1987;14:321-9.

25. Development Core Team R. R: A language and environment for statistical computing. R Foundation for Statistical Computing. 2011;Vienna, Austria.

26. Andersen PK, Klein JP, Knudsen KM, Tabanera y Palacios R. Estimation of variance in Cox's regression model with shared gamma frailties. *Biometrics*. 1997;53:1475-84.

27. Ying Z, Wei LJ. The Kaplan-Meier Estimate for Dependent Failure Time Observations. *Journal of Multivariate Analysis*. 1994;50:17-29.

28. Hannigan A, Lynch CD. Statistical methodology in oral and dental research: pitfalls and recommendations. *J Dent*. 2013;41:385-92.

29. Witter DJ, Kreulen CM, Mulder J, Creugers NHJ. Signs and symptoms related to temporomandibular disorders--Follow-up

of subjects with shortened and complete dental arches. *J Dent*. 2007;35:521-7.

30. Walter MH, Weber A, Pospiech P, Boning K, Busche E, Gerst J, et al. Randomisierte Studie zur verkürzten Zahnreihe: 5-Jahresergebnisse der Pilotstudie. *Deutsche Zahnärztliche Zeitschrift*. 2012;67:360-3.

31. Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. An observational cohort study on shortened dental arches--clinical course during a period of 27-35 years. *Clin Oral Investig*. 2013;17:859-66.

32. Warren JJ, Watkins CA, Cowen HJ, Hand JS, Levy SM, Kuthy RA. Tooth loss in the very old: 13-15-year incidence among elderly lowans. *Community Dent Oral Epidemiol*. 2002;30:29-37.

Chapter 5

Long-term follow-up indicates unimpaired oral health-related quality of life for people having shortened dental arches

Gerritsen AE, Witter DJ, Creugers NHJ. Long-term follow-up indicates unimpaired oral health-related quality of life for people having shortened dental arches. *Journal of Dentistry*. 2017;65:41-4.

Abstract

Aim: To assess and analyse OHRQoL of people with shortened dental arches (SDA) in a long-term cohort study.

Methods: All participants of a long-term cohort study on SDA who were still attending the university dental clinic and still had an SDA (SDA group) with 3-5 posterior occluding pairs and intact anterior areas, an SDA plus removable dental prosthesis (SDA plus PRDP group) or a complete dental arch (CDA group) completed the Dutch version of the Oral Health Impact Profile (OHIP-49NL) and additional questions on satisfaction with their dental status (yes/no). Mann-Whitney tests were performed for OHIP total scores and OHIP domain scores. The chance that the difference in median OHIP scores between the groups was larger than 6 OHIP units, was calculated by a bootstrapping procedure.

Results: Ten participants were eligible for the SDA group and 11 for the CDA group. The SDA plus PRDP group ($n = 1$) was excluded from analyses. Mean follow-up period was 29.3 ± 5.5 for the SDA group and 36.7 ± 5.5 years for the CDA group. Mean OHIP-49NL score was 13.9 ± 10.9 for the SDA group and 11.3 ± 8.6 for the CDA group. Differences in mean total scores and mean scores per domain were not statistically different. The probability that a difference in median OHIP total scores between groups was larger than 6 OHIP units was 0.25. Both groups showed high percentages of satisfaction with dental condition, except for dental appearance.

Conclusion: OHRQoL of people with a long-term SDA condition was similar to that of people with CDA.

Background

Today, the shortened dental arch (SDA) concept is globally accepted by dental professionals, but - despite a large body of circumstantial evidence that SDA provides sufficient functionality - not widely practiced [1]. The reluctance to practice the concept might be at least partially based on dentists' beliefs of patients' negative attitudes toward a shortened dental arch. Studies are needed in which patients are asked directly about how they perceive the SDA condition to assess their attitude.

Because an SDA condition is a consequence of tooth loss it might be expected that oral health-related quality of life (OHRQoL) is impaired. Indeed, a systematic review provided evidence that tooth loss is associated with impaired OHRQoL [2]. Outcomes of this meta-analysis indicated that not only the number, but also the location and distribution of missing teeth affect the severity of OHRQoL impairment. Loss of posterior teeth seems to have less negative impact on OHRQoL than loss of anterior teeth and distributions with fewer occluding pairs of teeth present are associated with more negative impacts.

Epidemiological studies on OHRQoL of people with SDA comprising a complete anterior region and 3 to 5 posterior occluding pairs reported no negative impacts on OHRQoL [3, 4]. These outcomes are based on cross-sectional data from a large study among relatively young individuals (aged 35-44 years) in Brazil [3] and from a telephonic interview survey among a general population in Australia with 80% of the participants being younger than 55 years [4]. Moreover, several clinical trials reporting on OHRQoL of people with an SDA compared SDA subjects with and without distal-extension removable dental prostheses (PRDP) [5-7]. The findings of these studies were inconclusive: one study [6] reported better OHRQoL for participants treated based on the SDA concept compared to PRDP treatment at one-year follow-up, another [7] reported similar results for participants with SDA with and without PRDP at one up to five years follow-up, whilst the third [5] (one-year follow-up) concluded that "prosthetic restoration (PRDP and implant-supported fixed dental prostheses (FDP)) for SDAs may benefit OHRQoL in patients needing replacement of missing posterior teeth". The authors of a recently conducted meta-analysis based on the one-year follow-up results of these three studies concluded that the SDA concept appears to be as acceptable as restoration with PRDP with respect to OHRQoL [8].

To better understand the degree of impact of having an SDA it is informative to compare OHRQoL of people with an SDA condition with that of people having a

complete dental arch (CDA) as a reference. In previous publications we reported on functionality, stability and sustainability of cohorts of people with SDA, SDA with distal-extension PRDP, and CDA after 27 – 35 years follow-up [9, 10]. The aim of the present study was to assess and analyse the OHRQoL of participants of this cohort study. Apart from statistical differences, the minimal important difference (MID) may be useful as a benchmark to assess what is clinically significant in terms of patient-based outcomes [11]. It was hypothesized that OHRQoL is most impaired in people with SDA and least in people with CDA, but that differences do not exceed the MID.

Methods

Data collection

Participants from a prospective observational cohort study on SDA, which started in 1981, were invited to participate in the present study. The initial longitudinal study included participants with an SDA with 3-5 posterior occluding pairs (POPs) and intact anterior areas with and without distal-extension PRPD, and participants with CDA. Teeth replaced by FDPs were considered as present. All participants were regular attenders of the Medical University dental clinic for check-ups and, if necessary, dental treatments. Detailed information on the sampling method has been presented in a previously published report [12].

For the present study, all SDA and CDA participants of the initial cohort who were still attending the dental school and still had an SDA (SDA group), SDA plus PRDP (SDA plus PRDP group) or CDA (CDA group) dental condition were invited to participate. The current dental condition of the participants was initially determined from their dental record and then verified by clinical examination. All participants completed the validated Dutch version of the Oral Health Impact Profile (OHIP-49NL) [13]. The reference period was 3 months and each statement was scored on a Likert type scale ranging from 0 (never) to 4 (very often). Additionally, questions about general satisfaction with dental condition, satisfaction with dental appearance and satisfaction with mastication were answered (yes/no).

Twenty-two participants were eventually eligible for this study: 10 for the SDA group, 1 for the SDA plus PRDP group, and 11 for the CDA group. One participant having an SDA plus PRDP condition at the start of the study ceased wearing her PRDP after 17 years. After she stopped wearing the PRDP the SDA condition of this participant

could be followed up for 15 years and was therefore included in the SDA group. All participants gave their informed consent. Because only 1 participant (67 years old male; 41 years follow-up; 3 posterior occluding pairs; OHIP total score 5, highest OHIP item score 2 (occasionally) for food catching ('functional limitation')) was available for the SDA plus PRDP group, this group was excluded from analyses. Individual domain scores were plotted to visualize the distribution of these scores for each group.

The ethical committee of the Radboud University Medical Center permitted the conduct of this study by decision cmo-nr 2010/316.

Statistical analysis

To compare OHRQoL of the SDA group and the CDA group, Mann-Whitney tests were performed for OHIP-49NL total scores and OHIP domain scores of the two groups using SPSS 22.0 software. The level of significance was set at $p = 0.05$. Moreover, the difference in OHIP outcomes between the SDA group and the CDA group were related to a reference minimal important difference (MID) value of 6 OHIP units [11, 14]. To calculate the chance that the difference in median OHIP scores between the groups was larger than 6 OHIP units, bootstrapping (1000 x re-sampling) was applied to construct a probability distribution for the difference in medians.

Results

Participants from both the SDA group and the CDA group had a similar mean age and age range (Table 5.1). The mean follow-up period was longest for the CDA group (36.7 ± 5.5 yrs.). Female participants were overrepresented in both groups (72 and 80% respectively).

The plot of individual domain scores (Fig 5.1) shows that the variation in scores between groups was rather small except for one individual in the SDA group with rather high scores for 'psychological disability' and 'handicap' and one individual in the CDA group with relative high scores for 'functional limitation' and 'physical pain'.

Mean OHIP-49NL score for the SDA group was 13.9 ± 10.9 ; for the CDA group this was 11.3 ± 8.6 (Table 5.2). Differences of mean total scores and mean scores per domain between the two groups were small and not statistically different (p -values ≥ 0.25).

Domain differences were largest for 'functional limitation' and 'pain': participants with SDA reported higher impact for 'functional limitation' whilst participants with CDA reported higher impact for 'pain'. Both groups showed high percentages of satisfaction with their dental condition and mastication, but not for dental appearance.

Table 5.1 Characteristics of the participants in the shortened dental arch (SDA) group and the complete dental arch (CDA) group

	SDA (n=10)	CDA (n=11)
Mean age in years (SD)	67.4 (8.2)	67.8 (9.6)
Range in age (years)	53.7 - 80.1	52.1 - 80.9
Gender distribution (% females)	80	72
Years of current dental condition (mean (SD))	29.3 (5.5)	36.7 (5.5)
Mean number (SD) of posterior occluding pairs at time of assessing OHRQoL	3.9 (0.7)	8.1 (0.8)

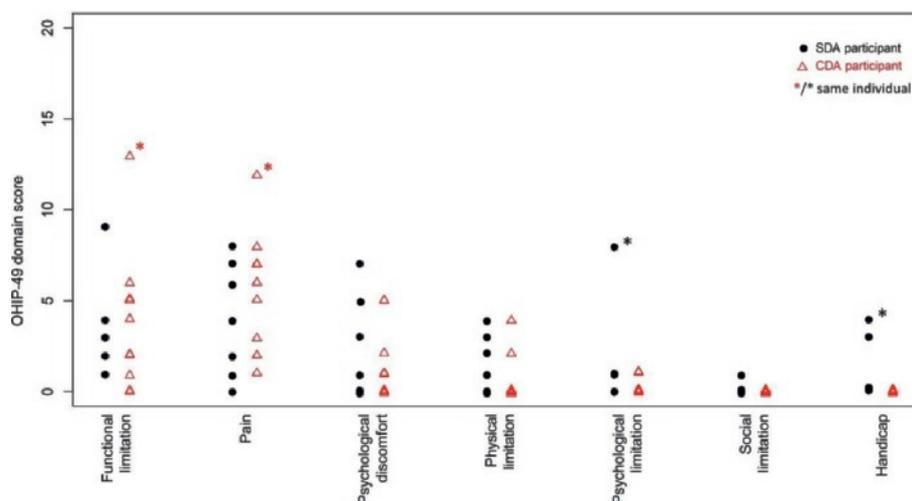


Figure 5.1 Plot of individual OHIP-49 domain scores.

Table 5.2 Mean (SD) and median of OHIP-49NL total scores, scores per domain, and percentage of participants satisfied with dental condition, dental appearance, and mastication for shortened dental arch (SDA) group and complete dental arch (CDA) group. P-values (Mann-Whitney tests) refer to comparisons of mean scores

	SDA group (n = 10)		CDA group (n = 11)		Mean difference of the means	p-value
	Mean (SD)	Median	Mean (SD)	Median		
OHIP total score	13.9 (10.9)	10.5	11.3 (8.6)	12	2.6	0.71
<i>OHIP domains:</i>						
Functional limitation	5.4 (3.2)	4	3.8 (3.6)	4	1.6	0.31
Pain	3.6 (2.7)	3	5.4 (3.2)	6	-1.8	0.25
Psychological discomfort	2.1 (2.7)	0.5	1.4 (1.9)	1	0.7	0.81
Physical limitation	1.0 (1.5)	0	0.5 (1.3)	0	0.5	0.47
Psychological limitation	1.0 (2.5)	0	0.2 (0.4)	0	0.8	0.61
Social limitation	0.1 (0.3)	0	0.0 (0.0)	0	0.1	0.71
Handicap	0.7 (1.5)	0	0.0 (0.0)	0	0.7	0.47
<i>Satisfaction (yes/no) with:</i>						
Dental condition (% yes)	90		81			
Dental appearance (% yes)	60		55			
Mastication (% yes)	90		100			

Based on the probability distribution, constructed using bootstrapping, the probability that the median OHIP total score for the SDA group was ≥ 6 OHIP units (MID) below that of the CDA group was 0.085, whilst the probability that the median OHIP total score for the SDA group was ≥ 6 OHIP units (MID) above that of the CDA group was 0.166.

Discussion

To our knowledge, a prospective observational cohort study that started in 1981 is the first and longest-running study on SDA [12]. Previous publications of this study reported outcomes regarding functionality, stability and sustainability of SDA, SDA with distal-extension PRDP, and CDA after 27 – 35 years follow-up [9, 10]. The present study is the first in this longitudinal study to report on OHRQoL; an earlier publication presented outcomes indirectly indicating OHRQoL related to the SDA condition by using a questionnaire assessing satisfaction with masticatory function [15]. Moreover, in that report only a comparison was made for SDA with and without PRDP whilst validated OHRQoL instruments did not exist at that time. It was remarkable that only 1 participant in the SDA plus PRDP group was available for this study. However, a previous report showed that the dental condition in this group was not stable: on the one hand a substantial number of participants in this group had their PRDP replaced by (implant-supported) FDPs. On the other hand, several participants lost some POPs and did not meet the inclusion criteria anymore [10]. With respect to possible selection bias in general, we have no indications that participants in the present study diverge from original participants lost to follow-up, i.e. people not attending the dental school anymore.

In general, mean OHIP-49 scores found in the present study were low compared to other studies [7, 16, 17] implying that the OHRQoL of the participants was relatively high. A possible reason for this discrepancy might be the positive experience of the long-term existence of the dental condition without substantial changes in that condition over time [10]. We found no statistically significant differences in OHIP-49NL scores between the SDA group and the CDA group. This absence of differences in OHIP scores might be explained by the samples sizes. The small sample size is the main limitation of this study, but is not surprising and almost inevitable after such a long period of follow-up. Regardless, the differences in OHIP scores between groups were small. Largest differences were found for the domains 'functional limitation' and 'pain' with more often perceived 'functional limitations' in the SDA group and more often 'pain' in the CDA group. The finding that people with SDAs report more limitations in functioning is consistent with a systematic review on masticatory performance presenting a 30% reduction of masticatory performance in comminution tests in people with SDA compared to people with CDA [18]. The lower scores in the domain 'pain' for the SDA group might be related to the lower number of teeth and therefore fewer teeth at risk for pain compared to CDA.

Although not a constant in different settings, the MID in OHIP-49 outcomes from other studies was used as a benchmark to assess what is clinically significant in terms of patient-based outcomes [11, 14]. With a difference in median scores of 1.5 OHIP units between the groups in the present study, which is substantially lower than a MID of 6 units as estimated in the reference studies, we consider the difference - even if differences in the mean scores would have been statistically significant- as clinically insignificant. However, although we did not find a clinical relevant difference between individuals with an SDA and those with a CDA, a larger sample is required to provide stronger evidence to reject or accept our hypothesis.

Another explanation for not finding differences in OHIP scores between the SDA group and the CDA group after this long follow-up period could be selection bias. One could argue that participants not satisfied with their SDA condition did receive replacement of posterior teeth in the past and as a result of that did not meet the inclusion criterion of having 3-5 POPs. However, as reported in a previous paper [10] none of the participants of the original SDA group had posterior teeth replaced leading to more than 5 POPs and therefore no participant has been excluded for this reason.

The additional questions about satisfaction did not reveal substantial differences between the groups: the percentages of satisfied participants were similar and high for dental condition and mastication, but relatively low for dental appearance. Because the satisfaction level for dental appearance for the SDA group was not lower than for the CDA group (60% for the SDA group and 55% for the CDA group), we consider tooth wear and/or discoloured teeth in this relatively aged sample a more feasible explanation for these low levels than the absence of posterior teeth.

The hypothesis that OHRQoL was most impaired in people with SDA and least in people with CDA could not be confirmed. The differences found did not exceed MID (6 OHIP units).

Conclusions

Differences in OHRQoL between people with a long-term SDA condition and people with CDA were small. Both groups showed high percentages of satisfaction for dental condition and mastication, but not for appearance.

References

1. Korduner EK, Söderfeldt B, Bagewitz IC, Von Steyern V, Wolf E. The Shortened Dental Arch concept from the perspective of Swedish General Dental Practitioners: a qualitative study. *Swed Dent J.* 2016;40:1-11.
2. Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NHJ. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual. Life Outcomes.* 2010;8:126.
3. Antunes JL, Tan H, Peres KG, Peres MA. Impact of shortened dental arches on oral health-related quality of life. *J Oral Rehabil.* 2016;43:190-7.
4. Tan H, Peres KG, Peres MA. Do people with shortened dental arches have worse oral health-related quality of life than those with more natural teeth? A population-based study. *Community Dent Oral Epidemiol.* 2015;43:33-46.
5. Fueki K, Igarashi Y, Maeda Y, Baba K, Koyano K, Sasaki K, et al. Effect of prosthetic restoration on oral health-related quality of life in patients with shortened dental arches: a multicentre study. *J Oral Rehabil.* 2015;42:701-8.
6. McKenna G, Allen PF, O'Mahony D, Cronin M, DaMata C, Woods N. The impact of rehabilitation using removable partial dentures and functionally orientated treatment on oral health-related quality of life: a randomised controlled clinical trial. *J Dent.* 2015;43:66-71.
7. Wolfart S, Müller F, Gerst J, Heydecke G, Marré B, Boning K, et al. The randomized shortened dental arch study: oral health-related quality of life. *Clin Oral Invest.* 2014;18:525-33.
8. Fueki K, Baba K. Shortened dental arch and prosthetic effect on oral health-related quality of life: a systematic review and meta-analysis. *J Oral Rehabil.* 2017;44:563-72.
9. Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. Increased risk for premolar tooth loss in shortened dental arches. *J Dent.* 2013;41:726-31.
10. Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. An observational cohort study on shortened dental arches-clinical course during a period of 27-35 years. *Clin Oral Invest.* 2013;17:859-66.
11. John MT, Reissmann DR, Szentpétery A, Steele J. An approach to define clinical significance in prosthodontics. *J Prosthodont.* 2009;18:455-60.
12. Witter DJ, Creugers NHJ, Kreulen CM, de Haan AF. Occlusal stability in shortened dental arches. *J Dent Res.* 2001;80:432-6.
13. van der Meulen MJ, John MT, Naeije M, Lobbezoo F. The Dutch version of the Oral Health Impact Profile (OHIP-NL): Translation, reliability and construct validity. *BMC Oral Health.* 2008;8:11.
14. Locker D, Jokovic A, Clarke M. Assessing the responsiveness of measures of oral health-related quality of life. *Community Dent Oral Epidemiol.* 2004;32:10-8.
15. Witter DJ, De Haan AF, Käyser AF, Van Rossum GM. A 6-year follow-up study of oral function in shortened dental arches. Part II: Craniomandibular dysfunction and oral comfort. *J Oral Rehabil.* 1994;21:353-66.
16. Armellini DB, Heydecke G, Witter DJ, Creugers NHJ. Effect of removable partial dentures on oral health-related quality of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont.* 2008;21:524-30.
17. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont.* 2008;21:72-4.
18. Liang S, Zhang Q, Witter DJ, Wang Y, Creugers NHJ. Effects of removable dental prostheses on masticatory performance of subjects with shortened dental arches: A systematic review. *J Dent.* 2015;43:1185-94.

Chapter 6

An empirically derived model of patient attitudes toward having a shortened dental arch condition

Gerritsen AE, de Blaauw N, Allen PF, Witter DJ, Creugers NHJ. An empirically derived model of patient attitudes toward having a shortened dental arch condition. *International Journal of Dentistry and Oral Health*. 2016;3

Abstract

Aim

To explore attitudes of people with shortened dental arches toward absent posterior teeth and posterior tooth replacements.

Methods

Participants were included after purposive sampling for a variety in age, gender, socioeconomic status, and for types of shortened dental arches with and without tooth replacement. Transcripts of face-to-face semi-structured interviews with open-ended questions were thematically analysed using MAXQDA software.

Results

After interviewing four females and five males (age ranging from 57 to 86 years), three main attitudes were identified: (1) neutral attitude resulting in 'without restraint acceptance of absent posterior teeth', and negative attitudes in which (2) 'resistance against having absent posterior teeth' prevailed, and (3) 'resistance against (needing a) tooth replacement' prevailed. Main themes regarding 'resistance against having absent posterior teeth' were functional discomfort ((assumed) functional problems) and emotional discomfort (feeling of not being intact). Reluctance to undergo treatment was an important reason to refuse tooth replacement resulting in secondary acceptance of absent posterior teeth. Main themes for 'resistance against tooth replacement' were a feeling of being handicapped that was associated with (needing a) dental prostheses and reluctance of having a foreign body in the mouth. Wearing a dental prosthesis in spite of a negative attitude was considered as secondary acceptance of tooth replacement.

Conclusions

In a conceptual model, three main attitudes toward the shortened dental arch condition were recognized resulting in direct or secondary acceptance of absent posterior teeth or demand for tooth replacement.

Background

Today, dentists in many countries consider the shortened dental arch concept an effective and efficient treatment strategy for patients with reduced dentitions [1, 2]. This is supported by clinical studies demonstrating no clinically relevant impairment with respect to perceived chewing function, nutritional status, and quality of life, and no or only slightly increased risks for caries, periodontal disease, signs and symptoms of temporomandibular disorders, and occlusal tooth wear for moderate shortened dental arches (SDAs), which are dentitions with a complete anterior region and a reduction of teeth starting posteriorly, and comprise of 3 to 5 posterior occlusal pairs [1-11].

Since the first international publication on the shortened dental arch concept in the early 1980s [12] fundamental societal transformations took place probably influencing patients' attitude toward the acceptance of absent posterior teeth. Whereas in the past tooth loss was often accepted as a part of a natural ageing process, nowadays patients expect to remain their teeth for life. Contemporary patients may have high expectations regarding (oral) health care, are assertive and have access to abundant information about disease and treatment options via media such as the Internet. Consequently, if tooth loss occurs they are more demanding regarding tooth replacement. Therefore, it can be assumed that, although a moderate shortened dental arch can fulfill the requirements of a functional dentition (1, 2, 4), an increasing number of patients inquire about the possibilities of replacement of their absent posterior teeth. This might be even true for patients missing posterior teeth for a lengthy period; whilst treatment options for shortened dental arches in the past were limited (lengthening the dental arch with a distal-extension removable dental prosthesis or no lengthening) at time treatment decisions were made, patients might reconsider this after learning about new treatment possibilities, such as implant treatment.

Patients increasingly expect a prominent role in the decision-making process (shared decision making) related to their health and treatment and expect (oral) healthcare providers to deliver personalized information and advice that is not merely based on evidence [13]. For an effective participatory discussion between patient and dentist it is imperative that the patient's view and attitude are understood and taken into account. The present qualitative study explores perceptions and attitudes of people with a shortened dental arch towards absent posterior teeth and replacement treatment. Such insights are considered useful in facilitating effective communication between clinician and patient.

Methods

To describe and explain patient's attitudes and views, we followed the grounded theory approach as described by Woods et al. (2016) [14]. This approach implies an iterative process of a systematic collection and thematic analyses of data. The purpose of the grounded theory is to develop a theory that conceptually explains human motivation or patterns of behaviour by means of a qualitative research methodology [14]. The 'Consolidated criteria for reporting qualitative research' (COREQ) for design and reporting criteria for qualitative studies were applied [15].

Recruitment of participants

The ethical committee of the Radboud University Nijmegen Medical Center permitted the conduct of this study by decision cmo-nr 2010/316.

Participants were selected by means of purposive sampling aiming to select informational rich cases for in-depth study. The purposive sampling aimed to include a variety of participants with respect to gender and socioeconomic status (SES), types of SDA (uni- and bilateral, and moderate (3 to 4 natural posterior occluding pairs) to extreme SDA (0 to 2 natural posterior occluding pairs)) with or without experience with posterior tooth replacement including fixed and partial removable dental prostheses. Electronic patient files of regular attendees of the Radboud University Nijmegen Medical Center, College of Dental Science clinic were searched to find people that fulfilled the following inclusion criteria: (1) dentitions with a complete anterior region and a reduction of teeth starting posteriorly with or without prosthodontic tooth replacement, (2) a confirmed duration of at least one year of having an SDA condition, and (3) aged 50 years and over.

Selected potential participants were invited by telephone for an interview; all agreed to participate. Prior to the interview the participants received a confirmation letter with written information about the study and the interview date and location.

Data collection

A trained female interviewer (AEG) conducted face-to-face semi-structured interviews with open-ended questions. Participants were aware of the fact that the interviewer was a dentist. However, she never treated them nor was there intention to do so in the future. Participants were informed that they would be interviewed about their shortened dental arch condition. The topic guide developed for the interviews was based on the work from Cronin et al. [16] and earlier published oral health models [17, 18]. All involved

researchers agreed upon the initial topic guide which included the topics 'oral condition', 'history of tooth loss', 'management of tooth loss' and, 'experience' (Table 6.1).

Table 6.1 Initial topic guide for the semi-structured interviews

Topic	Aspects to be explored
Oral condition	Perceived oral health and dental status
History of tooth loss	When? Reason? Feelings about tooth loss
Management of tooth loss	Why were lost posterior teeth (not) replaced? Other options / preferences considered Barriers Conscious decision? Level of knowledge / (missing) information / understanding
Experience	Appearance / self-esteem Speech / taste / eating / chewing process Social comfort / intimate relations Maintenance / oral hygiene Pain / comfort Acceptance / adaptation

The one to one interviews were conducted either in an office (not a clinical setting) or at the participants' homes, depending on their preference. During the interview presence of non-participants was avoided, but noted when this was inevitable. Interviews were digitally audio-recorded and notes were taken contemporaneous and afterwards by the interviewer.

Participants were asked to give information in response to the submitted topics as much as possible and were encouraged to raise any further relevant issues. Additionally, collected data included age, gender, SES and number of present teeth, fixed dental prostheses (FDPs) and partial removable dental prostheses (PRDPs) (Table 6.2). Confidentiality and anonymity of the participants were preserved. All participants were in good cognitive condition.

Table 6.2 Descriptive details of participants at time of the interview

Respondents*	Age	M/F	SES	Teeth present (including FDPs)	Posterior prostheses	Confirmed years of having an SDA condition
R1	63	M	High	17-25 47-35 and 37	FDP 13-(15)-17	15
R2	86	F	Middle	16-26 45-35	FDP (implants) 23, 24, 25 FDP 16-14; FDP 33-35	33
R3	72	F	High	16 and 14-25 45-36	FDP 23-26 Cantilever FDPs 34-36 and 43-45 (after 20 years lower PRDP)	35
R4	60	M	High	16-26 45-35	None	4
R5	65	F	Low	15-26 43-35	FDP 14-16 and 24-26 Lower PRDP	32
R6	57	M	Middle	15-25 and 27 44-36	None	2
R7	75	F	Low	17-25 45-35	FDP (implant) 25	25
R8	81	M	High	16-27 47-36	FDP 16-13 FDP (implants) 34, 35, 36	10
R9	70	M	Middle	17-27 45-34	Lower PRDP	40

* in sequence of interview date

SES = socioeconomic status; FDP = fixed dental prosthesis; PRDP = partial removable dental prosthesis; SDA = shortened dental arch.

Transcription and data analysis

All interviews were transcribed verbatim and were subjected to thematic content analysis. The software MAXQDA 2007 was used for organizing and managing the data analysis [19]. Data collection and analysis were carried out simultaneously aiming to improve the topic list coding system.

Two researchers (AEG & NB) coded the transcripts separately, but analysed the data together. The thematic analyses started by determining the inter-coder agreement for every transcript. After every three interviews an in-between-analysis was performed. Topics brought up by the respondents that were not included in the initial topic list were

added if considered relevant and the coding system was refined accordingly. Not-corresponding coding was discussed by the researchers until agreement was reached.

Several triangulation methods were used to ensure the trustworthiness and reliability of the study [20]. First, investigator triangulation was achieved by regular discussions between the researchers on interpretation of the data. Secondly, findings of observational notes, interviews and, occasionally, feedback sessions with experts formed the within-method triangulation. Reliability was further enhanced through the consistent use of techniques such as paraphrasing and summarization for clarification during the interviews [21], by increasing the credibility of interpretations through the use of participants' quotes and codes and (sub) themes [22]. Dental status as stated by the participant was crosschecked for congruency with their dental records.

Results

For the present study, 9 participants were interviewed; mean duration of the interviews 55 ± 23 (28 – 105) minutes. Brief descriptive details of the participants are presented in Table 6.2. Four females and five males, with ages ranging from 57 to 86 years presented with uni- or bilateral SDA of varying lengths with and without fixed and/or removable posterior tooth replacements. Shortest confirmed time of the duration of an SDA condition was 2 years and the longest was 40 years.

After analysis of the data three main attitudes toward shortened dental arches were identified and integrated in an empirical model: (1) a neutral attitude: an attitude of acceptance of absent posterior teeth without restraint (no demand for tooth replacement), (2) a negative attitude toward absent posterior teeth (resistance against having absent posterior teeth prevails) or (3) a negative attitude toward tooth replacement (resistance against (needing) tooth replacement prevails) (Fig. 6.1). The recruitment of participants was stopped after nine interviews because no new topics emerged and one or more participants represented the 'end-points/arms' of the model (informational saturation).

Neutral attitude; acceptance of absent posterior teeth without restraint

Participant R7 accepted her shortened dental arch without any restraint. She seemed to be hardly aware of the fact that she has no molars. The following quote illustrates her feeling about the absent molars.

Quote: R7: "I don't even notice." AEG: "You don't notice?" R7: "No not at all, no." AEG: "And do you have any feeling about this? Do you experience any feelings according to this?" R7: "No, not at all, no, no, no."

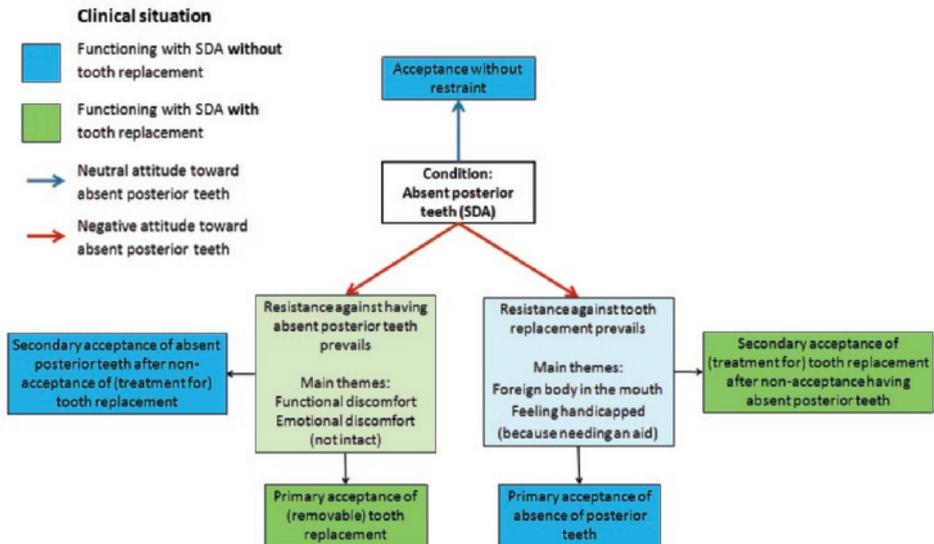


Figure 6.1 Illustrative diagram summarizing attitudes of patients with shortened dental arches toward absent posterior teeth and posterior tooth replacement.

A demand for replacement of molars seems to be completely absent.

R7 being asked about considering replacement: "No, because I have no complaints at all, and people don't see it, so"

The fact that R7 demanded an implant to replace tooth 25 indicates that resistance against treatment sec is no reason to avoid molar replacement. Acceptance of absent molars does not necessarily mean acceptance of absent premolars. In other words, SDA length seems to play a role in accepting absent posterior teeth, even for people who do not miss their molars at all.

Quote: R7: "... no, because after they extracted it [tooth 25], it felt empty such a big gap, I don't want that."

Negative attitude; resistance against having absent posterior teeth

The two major themes identified considering resistance against having absent posterior teeth were 'functional discomfort' because of (assumed) functional problems and 'emotional discomfort' because of a feeling not being intact. The following quote illustrates how absent molars can cause a feeling of not being intact and could influence emotional well-being:

Quote R6: *"[...] I worked as furniture maker for years on end and that is quite heavy labour [...] but that is 13 years ago now but these days when I do something I notice that everything is more difficult and goes slower ... and that fits with ... that when I feel blue sometimes ... when I then run my tongue along my teeth then my tongue slips through, and then it feels like something is lacking."*

For some participants, their negative attitude against having absent posterior teeth resulted in a positive mind-set towards tooth replacement (R5 and R8). People with this mind-set generally will experience improved functionality after tooth replacement.

Quote R5 (having a mandibular distal-extension RDP): *"Yes, yes, it's the first thing I do, put it in, the denture, huh? Sometimes, euh, I did forget it a couple of times, I thought hmmm, I miss something! [...] Yes, then you notice ... then you miss it for sure, then you are ... I think, oh, I must chew more on this side and not here because then I am biting on my gum, really, yeah. Yes, if you don't wear it than you really do miss it!"*

However, a negative attitude against having absent molars did not result by definition in a positive mind-set towards tooth replacement. Reluctance to undergo treatment was for most participants the main reason to decline tooth replacement; the remedy was considered worse than the disease. For example, R1 about tooth replacement by implants: *"I completely don't think about those kinds of things yet because when I see how other people mess around with that kind of ... euh ... what is called...bone transplantations and ... and taking stuff from hips and walking with sticks, no no, the only 'sticks' I have are for use on the golf course and nothing else!"* For both R1 and R4 reluctance to undergo treatment resulted in secondary acceptance of absent molars.

Negative attitude; resistance against (needing) tooth replacement

For the negative attitude 'resistance against tooth replacement' two main themes were identified: (1) a feeling of being handicapped (associated with needing a dental prostheses) or (2) aversion toward a foreign body in the mouth. This negative attitude always concerned PRDPs; fixed replacements were appraised equivalent to natural teeth. R2 for example expressed her aversion to have a foreign body in her mouth like this (about a dentist's proposal to provide a metal frame PRPD): *"No, that was never made."* AEG (referring to something R2 said earlier about appearance): *"Was that mainly because of your appearance you didn't want that?"* R2: *"No, not because of my appearance but I just didn't want to have something like that in my mouth, something that is not...something with a plate...that... I just didn't want to have that in my mouth!"*

Nevertheless, R2 accepted extensive treatment (three (implant supported) FDPs) for maintaining her SDA condition. R2 expressed adequate functioning without molars and acceptance of her dental condition.

R2 about chewing: AEG: *"Did I understand you well that you can chew as well as somebody with all molars?"* R2: *"Yes, yes, of course I cannot judge that, but I don't have the feeling that I am handicapped in that way, no no."*

R9 expressed a negative attitude towards medical aids in general because they emphasize being handicapped which makes him feel embarrassed.

R9 (about his hearing aids): *"Yes, yeah, yeah. I also have...I always call them my little plugs, hearing aids. Yes, I had those things behind my ear. I thought it was horrible, I felt deeply embarrassed. [...] Yes, it is visible, everybody...the bus for disabled people will come soon, from that song you know..."*

R9 expressed dislike for the sensation of a foreign body caused by his metal frame PRDP.

R9: *"I think my chopper is another story."* AEG: *"Your chopper? You mean your partial denture? Why?"* R9: *"Yes, because...yes, I think it is...it remains...eating is still...I call it different. You have something in your mouth, something artificial I would say. Because, despite of having it already for a long time...yes still...well, awkward is maybe too... I would rather be without than with [partial denture] ..., I eat tastier I guess."*

He says that he is still wearing his prosthesis most of the time because of (as he says) social reasons and his admiration for the handicraft involved in the making of his prosthesis (he is a retired engineer).

R9: *"Yes, I always have ..., I don't want to call it an aversion, but I think the piece of technique is quite beautiful and that they can make stuff like that and everything and I walk around with such a beautiful thing in my mouth!"*

During leisure he prefers not to wear his prosthesis: R9 (on being asked if there have been periods of not wearing his prosthesis): *"Yes, yeah, yeah, I can...I think...yes on holiday. Fourteen days and then...that we were in a hotel and I thought it is okay here."* But on social occasions he would wear his prosthesis. AEG: *"So when eating you don't benefit much from it [the denture]?"* R9: *"No, but let's say when I want to look on my Sunday best I put it in."* Wearing a PRPD in spite of a negative attitude against it was considered as 'secondary tooth replacement acceptance'.

For R3 none of both attitudes dominated; analysis of her interview showed both characteristics of resistance against having absent posterior teeth ('functional discomfort') and resistance against tooth replacement ('foreign body in the mouth'). This inconsistency is illustrated by the struggle between her conviction that wearing a PRPD is indispensable for adequate chewing whilst precisely this PRDP hinders adequate chewing.

R3 (being asked about wearing her distal-extension RDP for eating): *"No, I didn't put it in then."* AEG: *"You did not put it in?"* R3: *"No, not always, sometimes I did but not always although I know it is not right."* AEG: *"Is that so?"* R3: *"Yes, because you cannot chew well then. In that case, you actually only chew with your front teeth."*

Considering the feeling of a foreign body she mentioned: *"When you have it [distal-extension RDP] in for some time, I think, o, then it starts ..., it is for one thing strange in your mouth, because it is not of your own and then it also starts to hurt again and then it starts to grind, and you get sore spots, and then I think, off you go!"*

Discussion

This qualitative study showed different attitudes toward absent posterior teeth that fit in a model, which distinguishes between primary and secondary acceptance of an SDA condition. A qualitative study design was chosen to find a wide range of ideas,

perceptions and experiences of people with an SDA condition; the study was not aiming to search for quantitative data on the prevalence or distribution of these matters. When interpreting the results of this qualitative study, context specific conditions should be taken into account. The data were collected from a purposive sample of the dental school where the SDA concept was more or less 'invented' and often applied if applicable; therefore, informational bias might have influenced the participants' ideas. Moreover, this sample represents a cohort of relatively old regular attendees visiting the dental school for many years, indicating a positive attitude toward oral health care. The specific demand for dental implants by three participants (R2, R7, and R8) is an illustration of this positive attitude. Repeating this study in another setting would provide a broader basis for the model and clinical decision making for partially dentate people.

Although initially not intended, an empirical model started to evolve from the analyses of the first three interviews. In the attempt to get an overview of underlying issues of the participants' attitudes toward their shortened dental arch, a schematic model matured. This model summarizes the principle outcomes of the study and is rather an illustrative diagram than a theoretical framework. Ultimately all 'end-points/arms' of the model were represented by one or more participant, which was considered as an indication for data saturation. By this empirical model, we attempted to describe and illustrate attitudes of people towards their shortened dental arches, however the model needs further validation. Gender, age, SES, dental condition and its duration might influence the three attitudes and the primary or secondary acceptance of an SDA condition. The present study does not provide information to reveal extent nor direction of such influences. A systematic review synthesizing qualitative studies on patient's perceptions of loss of teeth and prosthetic rehabilitation recognized that negative impact of tooth loss is independent from variations in age, gender, cultural background and SES [23]. Recent studies on changes in oral health-related quality of life after prosthodontic rehabilitation showed ambiguous outcomes in associations between quality of life and age, gender and type of prosthodontic restoration [24, 25].

In essence, the method we used is close to the methodology that Nordenram et al. (2013) described to synthesize outcomes of qualitative studies: quotes (citations) were categorized into 'first level' themes, integrated and summarized into 'second level' themes and synthesized in our model as comprehensive 'third level' themes (resistance/acceptance of dental condition) [23]. In the present study, the underlying themes ('second level' themes) related to the participants' attitudes that were identified

were: 'functional discomfort', 'emotional discomfort', 'foreign body sensation', and 'feeling handicapped'. Awareness of the potential role of these themes by the clinician is pivotal in a shared decision making process in treatment planning. A proper shared decision making process includes a phase in which initial preferences are recognized, and deliberated in a way that they can evolve to an informed preference. According to the shared decision making model of Elwyn et al. (2012) it is essential to elicit what patients already know, and whether this knowledge is accurate [26]. Evidence obtained from qualitative studies on patient perspectives can provide clinicians with a better understanding of what may underlie patients' wishes. The use of standardized methods, such as proposed in the systematic review [23] is advised to strengthen the level of evidence.

With this model in mind it can be reasoned that information sharing is especially important if a patient does not feel content with his dental status, but is reluctant to pursue treatments replacing posterior teeth. It is advisable to ask patients who seem to accept having absent posterior teeth despite functional and/or emotional discomfort (secondary acceptance of absent posterior teeth), why they don't seek for tooth replacement. In this case, it is recommended to check whether the latter is based on accurate knowledge. In this study, some participants had some inaccurate ideas, especially on implant treatment. For example, R1 believed that he would need crutches because he presumed that bone had to be harvested from his hips. Communication, including evidence-based information, between dentist and patient is essential in this respect.

From patients who reluctantly wear a PRDP (secondary acceptance of tooth replacement) it is important to know why they do so. Again, if based on inaccurate knowledge, it is appropriate to inform the patients about risks and benefits of functioning with an SDA without replacement or about alternative treatment options for replacement.

The use of a shared decision process makes way for the so-called 'socio-dental approach'. This approach is a comprehensive needs assessment model that integrates both normative and subjective measurements in assessing needs for dental care [27]. Usually, an approach that addresses subjective impact-related needs leads to a reduction of prosthodontic treatment and only seldom to which fulfilling dental treatment, i.e. using dental "treatment" without a medical or dental therapeutic need [28, 29].

It should be noted that the interview responses are mainly from people who have had their dental condition for a long time. It is plausible that during this period the societal

transformations, increased expectations regarding oral health, and increased influence of media as mentioned in the introduction have changed participants' views, values and expectations over the years (response shift) [30]. It is also possible that the apparent acceptance of the SDA condition is due to a functional adaptation. However, we have no indications that response shifts due to societal changes made participants reconsider their previous treatment decisions over the years, except possibly for respondent R3, for whom her mandibular distal-extension RDP was replaced by two cantilever FDPs. We consider it likely that R3 was initially not well informed about alternative treatment options and that she revised the initial treatment decision after a 'new' option was introduced to her. This example shows that regular probing and/or verification of patients' wishes is meaningful for patients that express 'secondary acceptance' (active surveillance).

To our knowledge, the present study is the first to report on attitudes of patients who had an SDA condition for several years up to more than 40 years. Reasons to choose or refuse treatment for partial edentulism have been studied previously by Leles et al. (2009): a great variety in patients' reasons was reported such as complexity, similarity to natural teeth, better mastication [31]. The participants of the present study raised reasons alike; however, the design of this qualitative study does not allow drawing conclusions about the relative importance of the mentioned reasons. A qualitative study amongst people who recently received a PRDP reported difficulties in accepting the prosthesis [32]. The study reported that especially for people who are initially reluctant to treatment, clear information about consequences of wearing a partial denture is accommodating the eventual acceptance. This finding underlines again the importance of implementing a shared decision process in prosthodontics.

Conclusion

Three main attitudes toward the shortened dental arch condition were: (1) acceptance of absent posterior teeth without restraint, (2) resistance against having absent posterior teeth prevails, (3) resistance against (needing) tooth replacement prevails. These attitudes lead to direct or secondary acceptance of absent posterior teeth or demand for tooth replacement and were synthesized into a conceptual model.

References

1. Gotfredsen K, Walls AW. What dentition assures oral function? *Clin Oral Implants Res.* 2007;18 Suppl 3:34-45.
2. Kanno T, Carlsson GE. A review of the shortened dental arch concept focusing on the work by the Käyser/Nijmegen group. *J Oral Rehabil.* 2006;33:850-62.
3. Fueki K, Yoshida E, Igarashi Y. A structural equation model to investigate the impact of missing occlusal units on objective masticatory function in patients with shortened dental arches. *J Oral Rehabil.* 2011;38:810-7.
4. McKenna G, Allen PF, O'Mahony D, Cronin M, DaMata C, Woods N. The impact of rehabilitation using removable partial dentures and functionally orientated treatment on oral health-related quality of life: a randomised controlled clinical trial. *J Dent.* 2015;43:66-71.
5. McKenna G, Allen PF, O'Mahony D, Flynn A, Cronin M, DaMata C, et al. Comparison of functionally orientated tooth replacement and removable partial dentures on the nutritional status of partially dentate older patients: a randomised controlled clinical trial. *J Dent.* 2014;42:653-9.
6. Reissmann DR, Heydecke G, Schierz O, Marré B, Wolfart S, Strub JR, et al. The randomized shortened dental arch study: temporomandibular disorder pain. *Clin Oral Investig.* 2014;18:2159-69.
7. Tan H, Peres KG, Peres MA. Do people with shortened dental arches have worse oral health-related quality of life than those with more natural teeth? A population-based study. *Community Dent Oral Epidemiol.* 2015;43:33-46.
8. Walter MH, Hannak W, Kern M, Mundt T, Gernet W, Weber A, et al. The randomized shortened dental arch study: tooth loss over five years. *Clin Oral Investig.* 2013;17:877-86.
9. Walter MH, Marré B, Vach K, Strub J, Mundt T, Stark H, et al. Management of shortened dental arches and periodontal health: 5-year results of a randomised trial. *J Oral Rehabil.* 2014;41:515-22.
10. Wolfart S, Müller F, Gerss J, Heydecke G, Marré B, Boning K, et al. The randomized shortened dental arch study: oral health-related quality of life. *Clin Oral Investig.* 2014;18:525-33.
11. Zhang Q, Witter DJ, Bronkhorst EM, Bartlett DW, Creugers NHJ. Occlusal tooth wear in Chinese adults with shortened dental arches. *J Oral Rehabil.* 2014;41:101-7.
12. Käyser AF. Shortened dental arches and oral function. *J Oral Rehabil.* 1981;8:457-62.
13. Dieterich A. The modern patient - threat or promise? Physicians' perspectives on patients' changing attributes. *Patient Educ Couns.* 2007;67:279-85.
14. Woods P, Gapp R, King MA. Generating or developing grounded theory: methods to understand health and illness. *Int J Clin Pharm.* 2016;38:663-70.
15. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care.* 2007;19:349-57.
16. Cronin M, Meaney S, Jepson NJ, Allen PF. A qualitative study of trends in patient preferences for the management of the partially dentate state. *Gerodontology.* 2009;26:137-42.
17. Brondani MA, Bryant SR, MacEntee MI. Elders assessment of an evolving model of oral health. *Gerodontology.* 2007;24:189-95.
18. Locker D. Measuring oral health: a conceptual framework. *Community Dent Health.* 1988;5:3-18.
19. Kuckartz A. MaxQDA, the art of text analysis. VERBI software. Germany, Marburg: Research GmbH; 2007.
20. Denzin NK. The research act: A theoretical introduction to sociological methods. D. Chicago: Aldine Publishing Company; 1970.
21. Pope C, Mays N. *Qualitative research in health care.* 3 ed. Oxford: Blackwell publishing; 2006.
22. Krefting L. Rigor in qualitative research: the assessment of trustworthiness. *Am J Occup Ther.* 1991;45:214-22.
23. Nordenram G, Davidson T, Gynther G, Helgesson G, Hultin M, Jemt T, et al. Qualitative studies of patients' perceptions of loss of teeth, the edentulous state and prosthetic rehabilitation: a systematic review with meta-synthesis. *Acta Odontol Scand.* 2013;71:937-51.
24. Niesten D, Creugers N. Qualitative Research Is Important for All Prosthodontists. *Int J Prosthodont.* 2016;29:207-8.

- 25.** Omo J, Sede M, Esan T. Quality of life in subjects with shortened dental arch rehabilitated with removable metal-based partial dentures. *European Journal of Prosthodontics*. 2016;4:25.
- 26.** Elwyn G, Frosch D, Thomson R, Joseph-Williams N, Lloyd A, Kinnersley P, et al. Shared decision making: a model for clinical practice. *J Gen Intern Med*. 2012;27:1361-7.
- 27.** Sheiham A, Tsakos G. Oral health needs assessment. 2 ed. New Malden: Quintessence Publishing Co.; 2007. 59–79.
- 28.** Ab-Murat N, Sheiham A, Watt R, Tsakos G. Treatment needs and skill mix workforce requirements for prosthodontic care: a comparison of estimates using normative and sociodental approaches. *BMC Oral Health*. 2015;15:36.
- 29.** Ryu JI, Tsakos G, Sheiham A. Differences in prosthodontic treatment needs assessments between the standard normative and sociodental approach. *Int J Prosthodont*. 2008;21:425-32.
- 30.** Schwartz CE, Andresen EM, Nosek MA, Krahn GL, Measurement REPoHS. Response shift theory: important implications for measuring quality of life in people with disability. *Arch Phys Med Rehabil*. 2007;88:529-36.
- 31.** Leles CR, Martins RR, Silva ET, Nunes MF. Discriminant analysis of patients' reasons for choosing or refusing treatments for partial edentulism. *J Oral Rehabil*. 2009;36:909-15.
- 32.** Smith PA, Entwistle VA, Nuttall N. Patients' experiences with partial dentures: a qualitative study. *Gerodontology*. 2005;22:187-92.

Chapter 7

General discussion

Introduction

The central issue of this study was the contemporary relevance of the shortened dental arch concept as a viable treatment approach. As described in the general introduction, the concept was introduced in the previous century as a cost-effective treatment approach at the time of the 'caries epidemic' to retain a functional dentition without complex restoration of badly decayed molars and refrain from replacement of lost molars [1]. It appeared that a moderate shortened dental arch is well accepted by most individuals. However, the successful implementation of preventive measures and new treatment methods including oral implants, combined with increased treatment demand by more-demanding patients and an increased economic prosperity probably has changed patients attitude [2] toward having a shortened dental arch; a shortened dental arch might be considered as an 'inferior' situation that should be avoided or, when inevitable, be 'treated'. Consequently, one could argue that perhaps the shortened dental arch concept must be considered outdated and not longer relevant. However, the shortened dental arch concept appears to remain a topic of interest and discussion in the literature considering the fact that the number of papers published on the shortened dental arch is even increasing over time. Despite the increasing body of evidence from research, the shortened dental arch concept as a clinical treatment strategy remains topic of discussion [3].

The studies of this thesis are discussed integrally below. The first issue addressed is the impact of tooth loss in general on oral health-related quality of life (OHRQoL) (Chapter 2). The second issue discussed is the clinical course (Chapter 3) and the long-term sustainability of shortened dental arches (Chapter 4). Next, the impact of a shortened dental arches on OHRQoL specifically (Chapter 5) and the attitudes of people towards their shortened dental arch (Chapter 6) are elaborated on. Finally, the clinical relevance of the findings is discussed.

Impact of tooth loss on OHRQoL

It is increasingly recognized that the impact on quality of life (QoL) of disease and treatment of disease should be taken into account when assessing health status and evaluating treatment outcomes. Clinical indicators only are not sufficient to describe health status and it has been reported that people with chronic disabling disorders can perceive their quality of life as better than healthy individuals; i.e. poor health or

presence of disease does not inevitably mean poor QoL [4, 5]. Adaptive capacity and personal characteristics appear to influence patient's response to chronic disease. Tooth loss could also be considered as a chronic condition possibly leading to disability and therefore may impair OHRQoL. As far as we are aware of, the systematic review described in Chapter 2 is the first aiming to synthesize all available information on the relationship between tooth loss and OHRQoL. Data from this review and successive meta-analyses of observational studies provided fairly strong evidence that people indeed, on the whole, perceive tooth loss negatively. This is a consistent finding and appears to be independent of the OHRQoL measure used to assess subjective impact and context (e.g. country of residence). However, the severity of impairment of OHRQoL is probably context dependent [6] and the impact of cultural background remains subject for further exploration. In addition, it should be acknowledged that the included studies in the review reported at population level and this may mask heterogeneity at an individual level.

Interestingly, the results of the review suggest that the prevalence of negative impacts increases significantly once the number of teeth present drops below 17-20. On the basis of this finding it seems reasonable to suggest that application of the shortened dental arch approach remaining a moderate shortened dental arch is acceptable when considering OHRQoL. The findings of a recent literature review support this assumption [7]. Moreover, the impact of a shortened dental arch on OHRQoL specifically is investigated in the study described in Chapter 5. It should be recognized that dental status by itself does not necessarily predict OHRQoL. By incorporating subjective and objective assessment, our understanding of the consequences of oral disease and tooth loss for patients should improve [8]. Our qualitative study describing attitudes of participants towards their shortened dental arch contributes further to this understanding (Chapter 6).

Sample and validity

For the studies described in Chapters 3-6, clinical data and data from patient records were used from patients who participated in a prospective observational cohort study on shortened dental arches which started in 1981. The initial convenient sample comprised of participants attending the Nijmegen Dental School Clinic for routine oral check-up visits. This sample included individuals with a shortened dental arch in at least one jaw with 3-4 posterior occluding pairs: 74 individuals without extension and 25 individuals

with extension of their shortened dental arch by a partial removable dental prosthesis. In addition, 72 individuals with a complete dentition (reference group) were included. Detailed information on the sampling method can be found in a previously published report [9]. Clinical data and data from patient records collected from the initial sample were used to study the clinical course (Chapter 3) and long-term sustainability of shortened dental arches (Chapters 3 and 4). Additionally, patients from the initial sample who were still attending the dental school at the time of the study were invited for a clinical examination and to complete a questionnaire including the Dutch version of the Oral Health Impact Profile (OHIP-49NL). OHIP-49NL outcomes were used to assess the impact of a shortened dental arch on OHRQoL (Chapter 5). In addition, nine participants with shortened dental arches (five from the initial sample) were interviewed to investigate their attitudes towards their shortened dental arch (Chapter 6).

The common problem of loss to follow-up of participants in long-term follow-up studies was also encountered in the present study. Sixty-five percent of the dental records of the participants of the initial sample were not retrievable, mainly from patients who stopped attending the dental school clinic. We were able to collect clinical data and OHIP scores from about 18% of the initial sample. We consider the weakness of this study – the substantial loss to follow-up - compensated by the large number of subsequent recordings during a long follow-up period, which we consider the strength of this study.

It should be acknowledged that the small sample size and selected group of dental school patients might limit the external validity of the study, e.g. due to the strict maintenance protocols applied to these patients. However, still available patient records, which were archived after cancellation of subscription, did not provide hints pointing at bias due to selective drop-out. Moreover, the external validity of the findings of the studies might be also restricted because data were collected from people in one region in the Netherlands. In other regions or in other countries, issues such as quality of life might be perceived differently. With a mean follow-up period of 27 years and an average age of participants at the start of the initial study of 32 to 40 years, participants were relatively old at time of the investigations described in this thesis. Younger people might have different perceptions of oral health-related quality of life and attitudes toward shortened dental arches.

Clinical course and sustainability of shortened dental arches

The study presented in Chapter 3 demonstrate that shortened dental arches can be preserved for long periods as the majority of the shortened dental arch participants maintained their shortened dental arch status after a follow-up of 27 years and over. This was despite the increased risk for premolar tooth loss in shortened dental arch participants compared to participants with complete dental arches as found in the study described in Chapter 4. Although premolar loss obviously endangers the durability of a shortened dental arch condition, in the majority of the cases this condition was maintained by replacing lost premolars by fixed dental prostheses. On dentition level, the number of restorative interventions provided were not significantly different among the groups except that shortened dental arches received significantly more indirect restorations in the upper jaw than complete dental arches. Partially this was due to the high number of abutment crowns needed for the relatively high number of fixed dental prostheses provided for shortened dental arch participants.

In contrast to our hypothesis that shortened dental arches extended with partial removable dental prostheses are less sustainable than those without partial removable dental prostheses we found that adverse effects, such as tooth loss, were equally prevalent in both groups. Similar outcomes were found in a prospective clinical trial on tooth loss in shortened dental arches after a 3-year follow-up period [10]. However, a randomized controlled trial from the UK reported a significantly greater incidence of new and recurrent caries lesions in subjects with lower shortened dental arches restored with removable dental prostheses compared with distal-extension resin bonded bridges [11]. Regardless, in our study more than half of the participants with shortened dental arches extended with removable dental prostheses lost their initial dental status during follow-up. It is worthwhile to note that not all participants lost their shortened dental arch plus partial removable dental prosthesis status due to further tooth loss; three participants lost their group status because they stopped wearing their partial removable dental prosthesis. This indicates that patients often do not benefit from a partial removable dental prosthesis. Also when other outcomes are considered, partial removable dental prostheses seem not to be beneficial [12]; a study of Armellini et al. found that partial removable dental prostheses contribute to OHRQoL only if anterior teeth replacements are included [13]. Furthermore, Aras et al showed that partial removable dental prostheses in shortened dental arches did not improve masticatory performance [14] and McKenna et al. showed that both prosthetic rehabilitation to a functional dentition as well

as full rehabilitation including partial removable dental prostheses, did not improve the nutritional status as reflected in hematological markers [15].

The shortened dental arch concept was initially advocated as a cost-effective approach [1]. However, it should be realized that after an initial cost saving - by avoiding treatment of severely compromised molars - the average 'costs' of restorative maintenance of a shortened dental arch is at least as high as that of a complete dental arch, despite the fewer number of teeth to remain (Chapter 3). Nevertheless, we consider the shortened dental concept arch still as a 'cost-effective' treatment option because the majority of the shortened dental arch participants still had a shortened dental arch after approximately 30 years of follow-up. In contrast, given the lower sustainability (more than half of participants lost their initial status of having a shortened dental arch extended with a removable dental prosthesis) combined with additional expenses for maintenance of partial removable dental prostheses (including repairs and renewals) we consider extending a shortened dental arch with a removable denture prosthesis as not cost-effective. This presumption has been confirmed by a study from Ireland that demonstrated favourable cost-effectiveness for shortened dental arches without distal extension prostheses [16].

OHRQoL in people with long term shortened dental arches

To our knowledge, the study described in Chapter 5 is the first to report on OHRQoL of people having a shortened dental arch for approximately 30 years. In the study presented in Chapter 5 the validated Dutch version of the Oral Health Impact Profile (OHIP-49NL) was used. This instrument, consisting of 49 questions, was developed in 1994 [17] and today globally the most frequently used instrument to assess OHRQoL. In general, mean OHIP-49NL scores found in this study were low compared to other studies [13, 18, 19] implying that the OHRQoL of the participants was relatively high. An explanation for this discrepancy might be the positive experience with the long-term existence of the dental condition without substantial changes in that condition over time (Chapter 3). We found no statistically significant differences in OHIP-49NL scores between shortened dental arch and complete dental arch participants indicating that OHRQoL of participants with shortened dental arches is not inferior to that of participants with complete dental arches.

However, differences in OHIP scores might be masked by the small sample sizes. Nevertheless, the difference in median scores of 1.5 OHIP units between the shortened dental arch group and the complete dental arch group was substantially lower than the Minimal Important Difference (MID) of 6 units as estimated in the reference studies [20, 21]. Therefore, we consider the difference as clinically insignificant.

Patient attitudes towards shortened dental arches

Some clinical questions, particularly those about care rather than cure, are better answered with qualitative studies instead of quantitative studies because of the complex social and behavioural issues involved [22]. For this reason, we conducted a qualitative study to investigate different attitudes of people toward absent posterior teeth. In the attempt to get an overview of underlying issues of the participants' attitudes toward their shortened dental arch, a schematic model matured which distinguishes between primary and secondary acceptance of a shortened dental arch condition. The underlying themes that were identified were: (assumed) 'functional discomfort', 'emotional discomfort', 'foreign body sensation', and 'feeling handicapped'.

Awareness of the potential role of these underlying themes by the clinician is pivotal in a shared decision making process in treatment planning. A proper shared decision making process includes a phase in which initial preferences are recognized, and deliberated in a way that they can evolve to an informed preference. The use of a shared-decision process makes way for the so-called 'socio-dental approach'. This approach includes a comprehensive needs assessment model that integrates both normative and subjective measurements in assessing needs for dental care [23]. Usually, an approach that addresses subjective impact-related needs leads to a reduction of prosthodontic treatment and herewith prevents overtreatment [24, 25].

Seemingly incompatible results

On the face of it, the result of some studies in this thesis might seem incompatible: the systematic review showed that tooth loss is associated with impairment of OHRQoL (Chapter 2) whereas in the study described in Chapter 5 participants with shortened dental arch reported unimpaired OHRQoL. At the same time, negative attitudes toward having absent posterior teeth were observed in the qualitative study described in Chapter 6. Considering the systematic review, studies were included in which not only

the number of absent teeth was considered but also location and distribution. From the meta-analysis of these studies it was concluded that especially having unrestored anterior spaces and having fewer than 4 posterior occluding pairs negatively impacted OHRQoL. Since the inclusion criteria for shortened dental arches were having intact anterior regions and 3-5 posterior occluding pairs it is not surprising that we found no clinically relevant impairment of OHRQoL in the study described in Chapter 5.

Nevertheless, from individual depth-interviews it appeared that some participants had a negative attitude toward absent teeth because a feeling of not being intact. This attitude might influence emotional well-being and/or functional discomfort because of (assumed) functional problems. The reason why this negative attitude was not reflected in the OHIP-49NL scores is not clear. One explanation is that the OHIP instrument is unable to detect the effect of these attitudes on OHRQoL, but it is also possible that these attitudes do indeed not effect OHRQoL.

Implications for clinical practice

Although possibly less often applied than before, it can be concluded that the shortened dental arch concept is still a treatment strategy to be considered in treatment planning for patients with bad or absent molars. Moreover, the concept might be especially relevant for specific patient groups, for example people with low income or elders. Considering the latter group, it is expected that the proportion of people aged 65 and over in the Dutch population will increase from 18% in 2015 to 27% in 2040 [26], of which approximately a quarter may be categorized as frail [27]. Today's elder people have (partly) benefited from the improvements in preventive oral health care like the effective application of fluoride. These developments have resulted in a substantially larger and still growing proportion of older people that have retained their natural dentition [28]. These dentitions, however, are often reduced, extensively restored, and periodontally compromised as a result of an accumulation of damage incurred during life due to oral diseases, tooth wear, or trauma. Consequently, a high proportion of the elderly dentate population has a complex dental condition [28]. Management of these conditions becomes even more complex if patients present with problems within physical, psychological or social domains, and become increasingly frail. Frailty often leads to diminished oral self-care, avoidance of dental visits [29], and a limited propensity to undergo dental treatments. Although the retention of a complete natural dentition is often not realistic, the maintenance of a healthy and functional dentition is important for QoL in

this group. In this light, the shortened dental arch can be such a healthy and functional dentition and thus applying the concept can still be a useful treatment strategy. In this way, not only complicated curative treatments and inefficient tooth replacements but also treatments that may give course to future burden for the frail patient can be avoided. In addition, effective oral self-care will be easier to perform not only for the patient, but also for caregivers or (oral) health care professionals. Moreover, for elders it is often demanding to accept 'new' conditions after dental treatment. Such a diminished acceptance results from a reduced adaptability by decreasing neuroplasticity, i.e. the capacity of the central nervous system to reorganize itself by forming new neural connections [30]. Problems with adaptation to removable dental prostheses may be further provoked by pain and discomfort from sensitive mucous membranes or a dry mouth.

A shortened dental arch is a well defined, specific type of a reduced dentition and is probably therefore relatively often topic of clinical studies. Still, this is remarkable considering that a shortened dental arch condition is relative rare whereas reduced dentitions with random interruptions and reductions of the dental arches are very common, especially in the middle aged and older population [31-33]. It is unknown whether conclusions drawn from shortened dental arch studies are applicable on other reduced dentitions with comparable number of teeth and posterior occlusal pairs. To be able to categorize reduced dentitions the so-called hierarchical dental functional classification (HDFC) was developed [34]. Several studies using this classification system showed that a dentition with at least 10 teeth in each jaw, having complete anterior regions and 3-4 occluding pairs provides a functional dentition with molars having less effect on functionality than premolars [35-37]. However, further research is warranted to better understand the role of number, distribution, and type of present, absent, and replaced teeth.

References

1. Käyser AF. Shortened dental arch: a therapeutic concept in reduced dentitions and certain high-risk groups. *Int J Periodontics Restorative Dent.* 1989;9:426-49.
2. Dieterich A. The modern patient - threat or promise? Physicians' perspectives on patients' changing attributes. *Patient Educ Couns.* 2007;67:279-85.
3. Manola M, Hussain F, Millar BJ. Is the shortened dental arch still a satisfactory option? *Br Dent J.* 2017;223:108-12.
4. Decker SD, Schultz R, Wood D. Determinants of well-being in primary caregivers of spinal cord injured persons. *Rehabil Nurs.* 1989;14:6-8.
5. Sprangers MA, Aaronson NK. The role of health care providers and significant others in evaluating the quality of life of patients with chronic disease: a review. *J Clin Epidemiol.* 1992;45:743-60.
6. Steele JG, Sanders AE, Slade GD, Allen PF, Lahti S, Nuttall N, et al. How do age and tooth loss affect oral health impacts and quality of life? A study comparing two national samples. *Community Dent Oral Epidemiol.* 2004;32:107-14.
7. Fueki K. and Baba K. Shortened dental arch and prosthetic effect on oral health-related quality of life: a systematic review and meta-analysis. *J Oral Rehabil.* 2017; 44:563-72.
8. Locker D. Applications of self-reported assessments of oral health outcomes. *J Dent Educ.* 1996;60:494-500.
9. Witter DJ, Creugers NHJ, Kreulen CM, de Haan AF. Occlusal stability in shortened dental arches. *J Dent Res.* 2001;80:432-6.
10. Walter MH, Weber A, Marré B, Gitt I, Gerss J, Hannak W, et al. The randomized shortened dental arch study: tooth loss. *J Dent Res.* 2010;89:818-22.
11. Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J.* 2001;191:140-4.
12. Khan S, Musekiwa A, Chikte UM, Omar R. Differences in functional outcomes for adult patients with prosthodontically-treated and -untreated shortened dental arches: a systematic review. *PLoS One.* 2014;9:e101143.
13. Armellini DB, Heydecke G, Witter DJ, Creugers NHJ. Effect of removable partial dentures on oral health-related quality of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont.* 2008;21:524-30.
14. Aras K, Hasanreisoglu U, Shinogaya T. Masticatory performance, maximum occlusal force, and occlusal contact area in patients with bilaterally missing molars and distal extension removable partial dentures. *Int J Prosthodont.* 2009;22:204-9.
15. McKenna G, Allen PF, Flynn A, O'Mahony D, Damata C, Cronin M, et al. Impact of tooth replacement strategies on the nutritional status of partially-dentate elders. *Gerodontology.* 2011;53: 51-6.
16. McKenna G, Allen F, Woods N, O'Mahony D, Cronin M, DaMata C, et al. Cost-effectiveness of tooth replacement strategies for partially dentate elderly: a randomized controlled clinical trial. *Community Dent Oral Epidemiol.* 2014;42:366-74.
17. Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. *Community Dent Health.* 1994;11:3-11.
18. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont.* 2008;21:72-4.
19. Wolfart S, Müller F, Gerss J, Heydecke G, Marré B, Boning K, et al. The randomized shortened dental arch study: oral health-related quality of life. *Clin Oral Invest.* 2014;18:525-33.
20. John MT, Reissmann DR, Szentpetery A, Steele J. An approach to define clinical significance in prosthodontics. *J Prosthodont.* 2009;18:455-60.
21. Locker D, Jokovic A, Clarke M. Assessing the responsiveness of measures of oral health-related quality of life. *Community Dent Oral Epidemiol.* 2004;32:10-8.
22. Shneerson CL, Gale NK. Using mixed methods to identify and answer clinically relevant research questions. *Qual Health Res.* 2015;25:845-56.
23. Sheiham A, Tsakos G. Oral health needs assessment. 2 ed. New Malden: Quintessence Publishing Co.; 2007. 59–79 p.

- 24.** Ab-Murat N, Sheiham A, Watt R, Tsakos G. Treatment needs and skill mix workforce requirements for prosthodontic care: a comparison of estimates using normative and sociodental approaches. *BMC Oral Health*. 2015;15:36.
- 25.** Ryu JI, Tsakos G, Sheiham A. Differences in prosthodontic treatment needs assessments between the standard normative and sociodental approach. *Int J Prosthodont*. 2008;21:425-32.
- 26.** CBS. Prognose bevolking kerncijfers, 2012-2060, 18 december 2014 [2016 April 15].
- 27.** Campen van C. Kwetsbare ouderen. Sociaal en Cultureel Planbureau, Den Haag 2011.
- 28.** Kalsbeek H, Poortman JHG. Tandcariës in Nederland rond de eeuwwisseling. *Ned Tijdschr Tandheelkd*. 2003;110:516-21.
- 29.** Niesten D, van Mourik K, van der Sanden W. The impact of frailty on oral care behavior of older people: a qualitative study. *BMC Oral Health*. 2013;13:61.
- 30.** Trulsson M. Sensory-motor function of human periodontal mechanoreceptors. *J Oral Rehabil*. 2006;33:262-73.
- 31.** Haag DG, Peres KG, Brennan DS. Tooth loss and general quality of life in dentate adults from Southern Brazil. *Qual Life Res*. 2017;26:2647-57.
- 32.** Wiener RC, Wiener MA. Shortened dental arch and body mass index in adults 45-65 years of age: results from National Health and Nutrition Examination Survey 2005-2008. *Int Dent J*. 2015;65:277-82.
- 33.** Shin HS. The Number of Teeth is Inversely Associated With Metabolic Syndrome: A Korean Nationwide Population-Based Study. *J Periodontol*. 2017:1-13.
- 34.** Nguyen TC, Witter DJ, Bronkhorst EM, Pham LH, Creugers NHJ. Dental functional status in a southern vietnamese adult population-a combined quantitative and qualitative classification system analysis. *Int J Prosthodont*. 2011;24:30-7.
- 35.** Damyanov ND, Witter DJ, Bronkhorst EM, Creugers NHJ. Satisfaction with the dentition related to dental functional status and tooth replacement in an adult Bulgarian population: a cross-sectional study. *Clin Oral Investig*. 2013;17:2139-50.
- 36.** Nguyen TC, Witter DJ, Bronkhorst EM, Gerritsen AE, Creugers NHJ. Chewing ability and dental functional status. *Int J Prosthodont*. 2011;24:428-36.
- 37.** Zhang Q, Witter DJ, Bronkhorst EM, Creugers NHJ. Chewing ability in an urban and rural population over 40 years in Shandong Province, China. *Clin Oral Investig*. 2013;17:1425-35.

Chapter 8

Summary

Samenvatting

Summary

Chapter 1 provides an introduction into the shortened dental arch concept and into the underlying research questions and related main issues of the studies presented in this thesis. The shortened dental arch concept was introduced in the seventies of the last century and comprises a dental treatment strategy that can be followed when the most posteriorly located teeth (the molars) are seriously affected. A shortened dental arch is a dentition comprising the anterior teeth and bilaterally two pairs of opposing premolars. The *active* application of the shortened dental arch concept refers to a treatment strategy in which seriously affected molars are extracted instead of preserved by means of complex treatments. A *passive* application indicates maintaining an existing shortened dental arch and not to extend the dental arch by means of prosthetic replacement of absent molars.

At time of the introduction of the concept, a first consideration was the observation that people with a shortened dental arch generally were satisfied with their oral functions, including chewing function and dental appearance. Another consideration was of biological nature and concerned new occlusion concepts. Previously - based on morphological and mechanical principles - it was assumed that complete dental arches are necessary for a healthy orofacial system throughout life. In the sixties of the last century however - based on biological principles - it became clear that thanks to sensorimotor regulatory mechanisms in the orofacial system and adaptation capacities of patients, the presence of all posterior teeth, although desirable, is not definitely necessary. In addition, there was the consideration that in general molars are the teeth first affected by caries and periodontal diseases, and also the first to get lost, irrespective of possible complex and costly treatments. At the time of introduction of the concept, a final consideration was that a shortened dental arch could be extended only by means of a removable partial dental prosthesis. For many patients, this type of prosthesis caused more problems than solved possible problems.

Over the past fifty years, many clinical studies on shortened dental arches have been performed. These studies did not reveal significant shortcomings of this dental condition in terms of pathology, pathophysiology, or serious impairment of oral functions. However, there were reasons to re-evaluate the concept. First, available clinical evidence concerned cross-sectional or short term follow-up studies; long term follow-up studies on the sustainability of the of shortened dental arches was not available. Second, developments in dentistry facilitated new options for extending shortened dental arches

other than with removable dental prostheses, namely distal-extension bridges and implant-supported crowns or bridges. Moreover, significant socio-economic developments over the years can be identified. Nowadays, people generally have higher expectations of health care including oral health care, and are more demanding than 50 years ago. In addition, prosperity increased for many people and more people are willing to pay for costly fixed prosthodontic constructions. Based on these developments, the central question in the present thesis was: is the shortened dental arch concept – a small 50-years ago more or less driven by necessity - nowadays a too 'meager' and an obsolete treatment strategy?

With the above-mentioned developments, two main issues emerged for the studies in this thesis. First, perception of and oral health-related quality of life in people who experienced tooth loss, specifically of people with shortened dental arches (chapters 2, 5 and 6). A second issue in this thesis refers to the ultimate objective of oral health care: the preservation of a natural and functional dentition throughout life. So far, no long-term data on the sustainability of teeth in shortened dental arches were available (chapters 3 and 4).

Chapter 2 describes a systematic literature review on the relation between missing teeth and oral health-related quality of life. This review and the resulting meta-analyses differentiated explicitly between the impact of missing teeth in the anterior region and those missing in the posterior regions. All included studies showed that loss of teeth is associated with impairment of oral health-related quality of life. The degree of impairment of quality of life is associated with location and distribution of absent teeth: loss of anterior teeth has more impact than loss of posterior teeth and lower numbers of occluding pairs was associated with more impairment of oral health-related quality of life.

In **Chapter 3**, the clinical course of dentitions of people who previously participated in a cohort study on oral functions in shortened dental arches was compared. The cohort study included a group of subjects with shortened dental arches, a group of subjects with shortened dental arches plus a removable dental prosthesis, and a group of subjects with complete dental arches. Data on dental interventions - direct and indirect restorations, root canal therapy, extractions of teeth and tooth replacements - were obtained from patient records. After a follow-up period of about 30 years, 35% of the records of these subjects were still available; most subjects were 65 to 70 years of age at the end of the follow-up period. The mean number of the interventions per year did not differ significantly between subjects with shortened dental arches and subjects with complete dental arches with one exception: shortened dental arches received more

indirect restorations in the upper jaw, especially for teeth acting as abutment teeth for bridges after extraction of adjacent teeth. Contrary to our assumption, the mean number of interventions per year between subjects with shortened dental arches and subjects with shortened dental arches plus a partial dental prosthesis, did not differ significantly. At the end of follow-up, 20 out of the original 23 subjects with a shortened dental arch still had a shortened dental arch, while 6 out of 13 subjects with a shortened dental arch plus a prosthesis had retained this condition, and 20 out of 23 subjects with a complete dental arch still had this condition. Although not statistically significant, subjects with shortened dental arches plus a prosthesis had lost proportionally more teeth (63 teeth in 13 subjects) than subjects with shortened dental arches (67 teeth in 23 subjects).

It was concluded that the shortened dental arch concept still is a relevant strategy from the view of sustainability and cost-effectiveness. Shortened dental arches plus removable prosthesis were less cost-effective especially when manufacturing and maintenance costs of these prostheses were taken into account.

In the study described in **Chapter 4**, the sustainability of shortened dental arches in terms of the risk of receiving a first restoration in a not-restored tooth and the risk of tooth loss during the observation period was examined. This study was conducted among the same cohorts of subjects as the study described in chapter 3 and had the same observation period of about 30 years. Analyses were performed on the data obtained from the same patient records. Compared to people with complete dental arches, subjects with shortened dental arches showed a significantly greater risk to receive a first restoration, both in anterior teeth as well as in premolars. Compared to complete dental arches, in shortened dental arches the risk of losing premolars was higher, but not the risk of losing anterior teeth. Contrary to our assumption, subjects with shortened dental arches with a removable dental prosthesis had no greater risk to receive first restorations and to lose teeth compared to subjects without such a denture.

The conclusion was that subjects with shortened dental remain at risk for new restorations and loss of teeth.

In **Chapter 5** the oral health-related quality of life of subjects with shortened dental arches was compared to that of subjects with complete dental arches. The participants in this study were recruited from the Nijmegen university dental clinic, and had long-existing shortened or complete dental arches. To evaluate oral health-related quality of life, the Dutch version of the Oral Health Impact Profile (OHIP-49NL) was used, a questionnaire with 49 questions in 7 domains (functional limitation, pain, psychological discomfort, physical disability, mental limitation, social limitation, and

handicap). Apart from OHIP-total and domain scores, the likelihood that the difference of the median OHIP-total scores between the two groups is larger than the Minimal Important Difference (MID) was calculated. MID is a benchmark to assess what is clinically significant in terms of patient-based outcomes and in reference studies determined at 6 OHIP units. The mean OHIP-total and domain scores for both groups were low (good oral health-related quality of life) and did not differ significantly between the two groups. The probability that the median OHIP total score for the SDA group was ≥ 6 OHIP units (MID) higher than for the CDA group was 16.6%, whilst the probability that the median OHIP total score for the SDA group was ≥ 6 OHIP units lower than for the CDA group was 8.5%.

The conclusion was that people with a long-existing shortened dental arch perceive an oral health-related quality of life of comparable level to that of people with complete dental arches.

The qualitative study on the attitudes of subjects with shortened dental arches towards their dental situation is described in **Chapter 6**. The purposive sampling aimed to include participants with a variety in age, gender, socio-economic status, and types of prosthodontic treatments such as extension or no extension of their shortened dental arches. The semi-structured interviews with open questions were held with four women and five men (age 57 to 86 years) and were analyzed thematically.

Three main attitudes were identified: (1) a neutral attitude, resulting in acceptance of absent posterior teeth; a negative attitude in which (2) resistance against having absent posterior teeth prevailed, or a negative attitude in which (3) resistance against (needing) replacement of absent posterior tooth prevailed. The main themes related to resistance against having absent posterior teeth, were functional discomfort about (assumed) functional problems, and emotional discomfort (feeling of not being intact). Resistance to treatment was an important reason to refuse tooth replacement, resulting in secondary acceptance of having absent posterior teeth. Main themes for resistance against tooth replacement, were a feeling of being handicapped that was associated with having or needing a dental prosthesis, and having a foreign body in the mouth. Wearing a prosthesis in spite of these negative attitudes was considered as secondary acceptance of tooth replacement.

The conclusion was that in this conceptual model three main attitudes towards shortened dental arches were recognized resulting in direct or secondary acceptance of the condition or in a demand for tooth replacement.

Chapter 7 provides an integrated discussion of the studies in this thesis. The selection of participants from one university dental school limits the representativeness of the results of the studies, for example by the rigorous treatment protocols for periodical check-up visits applied at the dental school. The results of the studies on oral health-related quality of life can be biased because of relatively favorable clinical courses of the shortened dental arches over many years. Also, the advanced ages of the participants may have affected the outcomes: young people may have other attitudes toward their shortened dental arch and possible treatment options. In addition, the studies are performed in only one region in the Netherlands. For reason of representativeness, multicenter research, also among patients attending general practices, is preferable.

The two studies on the clinical course and the sustainability of shortened dental arches showed that shortened dental arches are able to last for long periods. Even though differences with people with complete dental arches were often not statistically significant, people with shortened dental arches remain, to a certain extent, people at risk for (further) tooth loss and needing restorations. It is therefore not surprising that the shortened dental arch concept accentuated an intensified (preventive) oral health care management.

More than half of the subjects with shortened dental arches with removable prostheses wore their prostheses no longer, in some cases because removable prostheses were replaced by fixed prosthodontic constructions. This shows once again that subjects with shortened dental arches apparently experience little benefit of distal-extension with removable prostheses. The oral health-related quality of life of the subjects with shortened dental arches had a similar level to that of subjects with complete dental arches. Nevertheless, the qualitative study revealed that subjects with shortened dental arches in majority still had mixed feelings about having shortened dental arch and/or about prosthodontic extension.

On the basis of the outcomes of the studies in this thesis, the shortened dental arch concept is still considered a valid and contemporary treatment strategy that deserves consideration in selected situations. However, before applying the concept (actively or passively), it is recommendable to explicitly discuss with the patient possible concerns and themes which came forward in the qualitative study. This improves the process of shared decision making with the goal to select well-founded treatment options and well-informed consent of patients.

The shortened dental arch concept seems particularly relevant for the growing group of older people with a natural dentition. People live longer and often have a dentition with complex problems, of which treatment is complicated by increasing general health problems. With increasing frailty, the maintenance of a dentition with shortened dental arches may be a more realistic and adequate oral health care plan compared to the pursuit of a dentition with complete dental arches or the (complete) dismantlement of the natural dentition.

Samenvatting

Hoofdstuk 1 is een inleiding in het verkorte-tandboogconcept en beschrijft de onderliggende onderzoeksvraag van dit proefschrift en de daaraan verbonden thema's. Het verkorte-tandboogconcept werd geïntroduceerd in de zeventiger jaren van de vorige eeuw. Met een verkorte tandboog wordt bedoeld een dentitie die bestaat uit alle frontelementen (voortanden) en links en rechts twee paren antagonistische premolaren (kleine kiezen). De actieve toepassing van het verkorte-tandboogconcept behelst een behandelstrategie waarbij ernstig aangetaste molaren, de achterste (grote) kiezen in de tandboog, worden verwijderd in plaats van deze te behouden door complexe behandelingen. Bij de passieve toepassing van het concept wordt een bestaande verkorte tandboog gehandhaafd en niet verlengd door de afwezige kiezen met een prothetische constructie te vervangen.

Bij de introductie van het verkorte-tandboogconcept speelde allereerst de overweging dat mensen met verkorte tandbogen over het algemeen tevreden zijn over hun gebitsfuncties zoals kauwen en het uiterlijk van hun gebit. Een andere overweging was biologisch van aard en betrof nieuwe occlusieconcepten. Eerder werd vanuit morfologische en mechanische uitgangspunten aangenomen dat volledige tandbogen noodzakelijk zijn voor een levenslang gezond orofaciaal systeem. In de zestiger jaren van de vorige eeuw werd vanuit een biologische benadering duidelijk dat dankzij sensorische regelmechanismen in het orofaciale systeem en het adaptatievermogen van de patiënt, de aanwezigheid van alle achterste gebitselementen weliswaar wenselijk, maar niet noodzakelijk is. Daarnaast was er de overweging dat in het algemeen juist de achterste kiezen als eerste worden aangetast door cariës en parodontale ziekten, en ook, vaak na complexe en kostbare behandelingen, als regel als eerste verloren gaan. Een laatste overweging toentertijd was dat een verkorte tandboog alleen verlengd kon worden door middel van een uitneembare partiële gebitsprothese die veel patiënten meer problemen bezorgde dan dat daarmee eventuele problemen werden verholpen.

In de afgelopen kleine vijftig jaar is veel klinisch onderzoek gedaan naar verkorte tandbogen zonder dat daarbij ernstige tekortkomingen van deze dentities in termen van pathologie, pathofysiologie, of ernstige afname van de gebitsfuncties aan het licht kwamen. Toch waren er redenen om het concept te re-evalueren. In de eerste plaats betrof het beschikbare klinisch onderzoek cross-sectioneel of korte termijn follow-up onderzoek: er was geen lange termijn onderzoek naar de bestendigheid van verkorte

tandbogen gedaan. In de tweede plaats waren er ontwikkelingen binnen de tandheelkunde, waardoor verlenging van verkorte tandbogen niet langer uitsluitend mogelijk was met uitneembare gebitsprothesen, maar ook mogelijk werd met vaste constructies: vrij-eindigende bruggen en implantaatgedragen kronen of bruggen. In de derde plaats hebben zich sociaaleconomische ontwikkelingen voorgedaan. Over het algemeen stellen mensen tegenwoordig hogere eisen aan de gezondheidszorg, inclusief de tandheelkundige zorg, dan 50 jaar geleden en is er meer aandacht voor levenskwaliteit. Daarnaast is bij veel mensen de welvaart toegenomen en kunnen meer mensen zich kostbare, vaste prothetische constructies veroorloven. De centrale vraag in het voorliggende proefschrift is dan ook of tegenwoordig het verkorte-tandboogconcept – dat een kleine 50 jaar geleden min of meer uit nood werd geboren - niet een erg ‘karige’ en inmiddels achterhaalde behandelstrategie is.

Met het bovenstaande zijn de twee zwaartepunten in het onderzoek in het kader van dit proefschrift aangeduid. Allereerst de mondgezondheid-gerelateerde levenskwaliteit zoals die wordt ervaren door mensen bij wie gebitselementen verloren zijn gegaan (hoofdstukken 2, 5 en 6). Een tweede zwaartepunt komt voort uit de uiteindelijke doelstelling van tandheelkundige zorg: behoud van een natuurlijke en functionele dentitie gedurende het gehele leven. De bestendigheid van verkorte tandbogen wordt geanalyseerd in de hoofdstukken 3 en 4.

In **Hoofdstuk 2** wordt een systematisch literatuuronderzoek beschreven over de mondgezondheid-gerelateerde levenskwaliteit van mensen met afwezige gebitselementen. Bij mensen met een verkorte tandboog zijn gebitselementen zoals eerder uiteengezet op een specifieke locatie in de tandbogen afwezig. Daarom is bij het literatuuronderzoek en de daaruit volgende meta-analyses ook nadrukkelijk gekeken naar de invloed van de locatie van de afwezige gebitselementen. Alle geïnccludeerde studies lieten zien dat het verlies van gebitselementen geassocieerd is met verlies van de mondgezondheid-gerelateerde levenskwaliteit. Daarbij was de mate van achteruitgang van levenskwaliteit geassocieerd met locatie en verdeling van de afwezige gebitselementen: verlies van voortanden heeft meer impact dan verlies van kiezen en een verminderd aantal occluderende paren was geassocieerd met een lagere mondgezondheid-gerelateerde levenskwaliteit.

In **hoofdstuk 3** is het klinisch verloop van de dentities van personen gevolgd die eerder in een cohortonderzoek naar de gebitsfuncties bij verkorte tandbogen hadden geparticipeerd. De studie bestond uit cohorten van personen met een verkorte tandboog, personen met een vergelijkbare verkorte tandboog met een partiële gebitsprothese, en

personen met volledige tandbogen. De gegevens over directe en indirecte restauraties, wortelkanaalbehandelingen, extracties van gebitselementen en prothetische vervangingen werden verkregen uit de patiëntdossiers in de periode dat zij patiënt waren bij de tandheelkunde kliniek van het Radboudumc. Na de lange follow-up periode van ongeveer 30 jaar was van 35% van deze mensen het patiëntdossier nog beschikbaar; de meesten hadden na die periode een leeftijd in de orde van 65 tot 70 jaar. Het gemiddeld aantal interventies per jaar verschilde niet significant tussen mensen met verkorte tandbogen en mensen met complete tandbogen met één uitzondering: mensen met verkorte tandbogen hadden meer indirecte restauraties in de bovenkaak gekregen, vooral bij pijlerelement ten behoeve van bruggen na extractie van buurelementen. Ook verschilde het gemiddeld aantal interventies per jaar niet tussen mensen met verkorte tandbogen en die met verkorte tandbogen met een partiële gebitsprothese. Aan het eind van de onderzoeksperiode hadden 20 van oorspronkelijke 23 personen met een verkorte tandboog nog steeds een verkorte tandboog, terwijl 6 van 13 personen met een verkorte tandboog met een partiële gebitsprothese deze gebitssituatie hadden behouden. Hoewel niet statistisch significant, verloren de mensen met een verkorte tandboog met een gebitsprothese proportioneel meer gebitselementen (63 gebitselementen in 13 personen) dan de mensen met verkorte tandbogen (67 elementen in 23 personen).

Geconcludeerd werd dat het verkorte-tandboogconcept nog steeds een relevante behandelstrategie is, ook vanuit het oogpunt van kosteneffectiviteit: in zijn algemeenheid bleken verkorte tandbogen ook na 30 jaar functioneren nog intact. Verkorte tandbogen met uitneembare gebitsprothese waren minder kosteneffectief, met name vanwege de kosten van de vervaardiging en het onderhoud van de gebitsprothesen.

Ook het onderzoek beschreven in **Hoofdstuk 4** gaat in op de bestendigheid van verkorte tandbogen. In dit geval werd de kans onderzocht die mensen gedurende de observatieperiode hadden om een eerste restauratie te krijgen in een gaaf gebitselement, en de kans dat gebitselementen werden geëxtraheerd. Het betreft onderzoek bij dezelfde cohorten van mensen, eveneens gedurende een observatieperiode van ongeveer 30 jaar met data verkregen uit de patiëntdossiers zoals beschreven in hoofdstuk 3. Vergelijken met mensen met complete tandbogen, hadden mensen met verkorte tandbogen een significant grotere kans om een eerste restauratie te krijgen, zowel in de frontelementen als in de premolaren, en was ook de kans op het verlies van premolaren groter, maar niet de kans op verlies van frontelementen. In tegenstelling tot de verwachting hadden mensen met verkorte tandbogen met een

uitneembare partiële gebitsprothese geen grotere kans op eerste restauraties en verlies van gebitselementen vergeleken met mensen zonder een dergelijke prothese.

De conclusie was dat mensen met een verkorte tandboog in zekere zin toch risicopersonen zijn voor nieuwe restauraties en verlies van gebitselementen.

In **hoofdstuk 5** wordt de mondgezondheid-gerelateerd levenskwaliteit bij personen met verkorte tandbogen vergeleken met die van personen met complete tandbogen. Alle participanten hadden een langdurig bestaande verkorte of volledige tandboog. Om de mondgezondheid-gerelateerd levenskwaliteit te evalueren werd gebruik gemaakt van de Nederlandse versie van de Oral Health Impact Profile (OHIP-49NL), een enquête met 49 vragen in 7 domeinen: functiebeperking, pijn, psychisch ongemak, lichamelijke beperking, psychische beperking, sociale belemmering, en handicap. Behalve OHIP-totaal- en domeinscores werd ook de kans berekend dat het verschil van de mediane OHIP-totaalscores tussen de twee groepen groter zou zijn dan de 'Minimal Important Difference' (MID). De MID is een referentiemaat voor klinische, voor de patiënt relevante verschillen in OHIP scores en in referentiestudies vastgesteld op 6 OHIP eenheden. De gemiddelde OHIP-totaal- en domeinscores van beide groepen waren laag wat duidt op een goede mondgezondheid-gerelateerde levenskwaliteit en verschillen niet significant tussen de twee groepen. De kans dat de mediane OHIP totaalscores voor de verkorte tandboog groep ≥ 6 OHIP eenheden (MID) hoger was dan de mediane OHIP totaalscores van de complete tandboog groep was 16.6% en de kans dat deze ≥ 6 OHIP eenheden lager was, was 8,5%.

De conclusie was dat mensen met een reeds lang bestaande verkorte tandboog een mondgezondheid-gerelateerd levenskwaliteit ervaren die vergelijkbaar is met die van mensen met complete tandbogen.

Het kwalitatieve onderzoek naar de beleving en gevoelens van mensen met een verkorte tandboog over hun gebitssituatie is beschreven in **hoofdstuk 6**. De doelgerichte steekproef had als doel mensen te selecteren met een zekere variatie in leeftijd, geslacht, socio-economische status, en prothetische behandeling, zoals verlenging of geen verlenging van hun verkorte tandboog. De semigestructureerde interviews met open vragen werden gehouden met vier vrouwen en vijf mannen (leeftijd 57 tot 86 jaar) en daarna thematisch geanalyseerd. Uit deze analyse kwam naar voren dat mensen met een verkorte tandboog dit op hoofdlijnen op drie verschillende manieren beleven: (1) een neutrale houding, resulterend in de acceptatie van de afwezige kiezen; (2) een negatieve houding waarin weerstand tegenover het hebben van afwezige kiezen overheerste, of (3) een negatieve houding waarbij weerstand tegen (het nodig zijn) van vervanging van

kiezen overheerste. De belangrijkste thema's bij weerstand tegen het hebben van afwezige kiezen waren ongemak vanwege (veronderstelde) functionele problemen en van emotionele aard vanwege het gevoel 'niet compleet' te zijn. Ondanks deze gevoelens van ongemak was de weerstand om behandeling te ondergaan een belangrijke reden om vervanging van de afwezige kiezen af te wijzen, wat resulteerde in een secundaire acceptatie van die afwezigheid. De belangrijkste thema's bij weerstand tegen prothetische vervanging van de afwezige kiezen weerstand tegen het hebben van een vreemd, niet lichaamseigen voorwerp in de mond en waren het gevoel gehandicapt te zijn door een gebitsprothese of deze nodig te hebben. Het dragen van een gebitsprothese ondanks deze negatieve opvattingen kan worden beschouwd als een secundaire acceptatie van de prothetische voorziening ter vervanging van de afwezige kiezen.

De conclusie was dat in dit conceptuele model in het algemeen drie belevingen tegenover het hebben van een verkorte tandboog onderkend konden worden die resulteerden in een directe of in indirecte acceptatie van de verkorte tandboog of in een acceptatie van de prothetische vervanging van afwezige kiezen.

Hoofdstuk 7 bevat een integrale discussie over de studies in dit proefschrift. De selectie van de participanten of de patiëntdossiers in de onderzoeken naar de bestendigheid van (de gebitselementen van) verkorte tandbogen kan de representativiteit van de uitkomsten van de studies hebben beperkt, bijvoorbeeld door de strikte toepassing van protocollen voor periodiek mondonderzoek en eventuele behandelingen in de tandheelkunde kliniek van het Radboudumc. De uitkomsten van de studies naar de mondgezondheid-gerelateerde levenskwaliteit kunnen vervolgens zijn beïnvloed doordat de participanten een relatief gunstig klinische verloop van hun dentitie hadden gedurende vele jaren. Ook de gevorderde leeftijd van de participanten kan van invloed zijn geweest: jongeren hebben wellicht andere opvattingen over hun verkorte tandboog en over eventuele behandeling. Daarenboven zijn de onderzoeken gedaan in één regio binnen Nederland.

De twee studies naar het klinisch verloop en de bestendigheid van verkorte tandbogen laten zien dat verkorte tandbogen lange tijd kunnen functioneren. Alhoewel verschillen met mensen met complete tandbogen veelal niet significant waren, bleken mensen met verkorte tandbogen toch in enigerlei mate risico-personen te zijn om (eerste) restauraties in gebitselementen te krijgen en voor (verder) verlies van gebitselementen. Het is dan ook niet verwonderlijk dat in het verkorte-tandboogconcept

steeds wordt benadrukt om aan patiënten met een verkorte tandboog een verhoogde (preventieve) zorg te geven.

Meer dan de helft van de mensen met een uitneembare gebitsprothese, droeg die niet meer; in een aantal gevallen omdat later voor vaste constructies was gekozen. Dit laat opnieuw zien dat patiënten met verkorte tandbogen kennelijk weinig profijt ervaren van tandboogverlenging met uitneembare gebitsprothesen. De mondgezondheid-gerelateerde levenskwaliteit van de mensen met verkorte tandbogen bleek van vergelijkbaar niveau met die van de mensen met complete tandbogen. Maar ook bleek uit het kwalitatieve onderzoek dat mensen met verkorte tandbogen in meerderheid gemengde gevoelens hebben over hun verkorte tandboog dan wel over het prothetisch verlengen daarvan.

Op grond van de uitkomsten van de onderzoeken in dit proefschrift wordt het verkorte-tandboogconcept nog steeds als een valide en hedendaagse behandelstrategie beschouwd die overweging verdient in geselecteerde situaties. Maar alvorens te besluiten om het concept actief of passief toe te passen, is het aanbevelenswaardig om de belevingen en thema's die in het kwalitatief onderzoek naar voren kwamen, expliciet met de patiënt te bespreken. Dit heeft ten doel om het proces van gezamenlijke besluitvorming te verbeteren en daarmee tot verantwoorde behandelkeuzen en een werkelijk goed geïnformeerde toestemming (informed consent) te komen.

Het verkorte-tandboogconcept is met name relevant voor de steeds groter wordende groep ouderen met een natuurlijke dentitie. Ouderen worden bovendien steeds ouder en hebben veelal een dentitie met complexe problemen, waarvan de behandeling nog extra wordt bemoeilijkt door toenemende gezondheidsproblemen. Met toenemende kwetsbaarheid is het behoud van een dentitie met verkorte tandbogen wellicht een reëler en doelmatiger zorgdoel dan het streven naar een dentitie met complete tandbogen als alternatief van het (geheel) afbouwen van de natuurlijke dentitie.

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Curriculum Vitae

Anneloes Ellen Gerritsen werd geboren op 22 oktober 1975 in Almelo. Zij ging daar naar de Montessori school en later naar de OSG Erasmus waar zij in 1994 haar VWO diploma behaalde. In hetzelfde jaar begon zij aan de studie tandheelkunde aan de Radboud Universiteit Nijmegen en behaalde in 2000 haar tandartsdiploma. Daarna is zij als docent aan de slag gegaan bij de subfaculteit Tandheelkunde, afdeling Orale Functieleer (thans afdeling Tandheelkunde, vakgroep Orale Functieleer) van het Radboudumc en heeft zij als algemeen practicus in verschillende tandartsenpraktijken gewerkt. In 2007 heeft zij enkele maanden aan de Cork University Dental School and Hospital gedooceerd in het kader van een docentuitwisselingsprogramma. Onder begeleiding van professor P.F. Allen is zij daar gestart met het formuleren van de eerste onderzoeksvragen voor dit promotieonderzoek. Vanaf 2013 heeft zij het Gerodontologie onderwijs in de opleiding tandheelkunde overgenomen van professor C. de Baat en is zij daarnaast werkzaam als verpleeghuistandarts bij Stichting de Waalboog in Nijmegen.

List of publications

1. Gerritsen AE. Pijn na het cementeren van een gegoten restauratie. *Ned Tijdschr Tandheelkd.* 2004;111:311-5.
2. Gerritsen AE. Vervanging van een centrale bovenincisief in een gebit met diastemen in het front. In: *Tandheelkundige casuïstiek.* Houten, Bohn Stafleu van Loghum; 2008. p. 254-8.
3. Gerritsen AE, Sarita P, Witter DJ, Kreulen CM, Mulder J, Creugers NHJ. Esthetic perception of missing teeth among a group of Tanzanian adults. *Int J Prosthodont.* 2008;21:169-73.
4. Creugers NHJ, Witter DJ, Van 't Spijker A, Gerritsen AE, Kreulen CM. Occlusion and temporomandibular function among subjects with mandibular distal extension removable partial dentures. *Int J Dent.* 2010;2010:doi:10.1155/2010/807850
5. Damyanov ND, Witter DJ, Gerritsen AE, Creugers NHJ. Dental laboratory production of prosthetic restorations in a population in sofia, bulgaria: a descriptive study. *Int J Dent.* 2010;2010:doi: 10.1155/2010/286192
6. Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NH. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual Life Outcomes.* 2010;8:126.
7. Gerritsen AE, Creugers NH. Levenskwaliteit bij verlies en varvanging van gebitselementen. *Ned Tijdschr Tandheelkd.* 2011;118:210-3.
8. Nguyen TC, Witter DJ, Bronkhorst EM, Gerritsen AE, Creugers NHJ. Chewing ability and dental functional status. *Int J Prosthodont.* 2011;24:428-36.
9. Witter DJ, Hoefnagel RA, Gerritsen AE, Creugers NHJ. Kronen en bruggen - functies en typen. *Ned Tijdschr Tandheelkd.* 2012;119:595-605.
10. Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NH. Increased risk for premolar tooth loss in shortened dental arches. *J Dent.* 2013;41:726-31.
11. Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NH. An observational cohort study on shortened dental arches--clinical course during a period of 27-35 years. *Clin Oral Investig.* 2013;17:859-66.

- 12.** Witter DJ, Gerritsen AE, van 't Spijker A, Creugers NHJ. Kronen en bruggen in realtie tot het occlusiesysteem. *Ned Tijdschr Tandheelkd.* 2013;120:68-80.
- 13.** Zhang Q, Witter DJ, Gerritsen AE, Bronkhorst EM, Creugers NHJ. Functional dental status and oral health-related quality of life in an over 40 years old Chinese population. *Clin Oral Investig.* 2013;17:1471-80.
- 14.** Kreulen CM, Gerritsen AE, Creugers NH. Resin composite restorations for the elderly patient. *Gerodontology.* 2014;31:243-4.
- 15.** Witter DJ, Gerritsen AE, de Baat C, Creugers NHJ. Prothetische vervanging van afwezige gebitselementen. Indicaties voor vaste en uitneembare prothetische constructies *Ned Tijdschr Tandheelkd.* 2014;121:45-56.
- 16.** de Baat C, Gerritsen AE, van der Putten GJ, van der Maarel-Wierink CD. Proefschriften 25 jaar na dato 41. Aanpassingsvermogen van ouderen. *Ned Tijdschr Tandheelkd.* 2015;122:455-60.
- 17.** Gerritsen AE, Witter DJ, Creugers NHJ. Is het concept van de verkorte tandboog nog van deze tijd? In: *Het tandheelkundig jaar 2016.* Houten, Bohn Stafleu van Loghum; 2015. p. 191-202.
- 18.** Niesten D, van der Sanden WJ, Gerritsen AE. De invloed van kwetsbaarheid op mondzorggedrag en tandsbezoek van ouderen. *Ned Tijdschr Tandheelkd.* 2015;122:210-6.
- 19.** de Baat C, Gerritsen AE, de Baat-Ananta M, de Baat P. De (vermeende) pathologische invloed van fibromyalgie op het orofaciale systeem. *Ned Tijdschr Tandheelkd.* 2016;123:148-53.
- 20.** Gerritsen AE, de Blaauw N, Allen PF, Witter DJ, Creugers NHJ. An empirically derived model of patient attitudes toward having a shortened dental arch condition. *International Journal of Dentistry and Oral Health.* 2016;3.
- 21.** Zhang Q, Jing Q, Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. Dental status of an institutionalized elderly population of 60 years and over in Qingdao, China. *Clin Oral Investig.* 2016;20:1021-8.
- 22.** Zhang Q, Li T, Gerritsen AE, Witter DJ, Bronkhorst EM, Creugers NHJ. Missing teeth and prosthodontic replacement in an institutionalized dentate population of 60 years and older in Qingdao, China. *Int J Prosthodont.* 2016;29:389-98.

23. de Baat C, de Baat P, Gerritsen AE, Flohil KA, van der Putten GJ, van der Maarel-Wierink CD. Risks, consequences, and prevention of falls of older people in oral healthcare centers. *Spec Care Dentist*. 2017;37:71-7.

24. Gerritsen AE, Witter DJ, Creugers NHJ. Long-term follow-up indicates unimpaired oral health-related quality of life for people having shortened dental arches. *J Dent*. 2017;65:41-4.

