Treatment of large overjet in preadolescents

Studies of treatment effects, cost assessment and patient perceptions - a comparison of two removable functional appliances

Emina Čirgić

Department of Orthodontics
Institute of Odontology
Sahlgrenska Academy at University of Gothenburg

UNIVERSITY OF GOTHENBURG

2017

Cover illustration: Eva Ryberg

Treatment of large overjet in preadolescents

emina.cirgic@vgregion.se

ISBN 978-91-629-0059-5 (PDF)

ISBN 978-91-629-0060-1 (Print)

Printed in Gothenburg, Sweden 2017

Printed by Ineko, AB, Gothenburg

To my Family & Bobo

“I had a little thing with my thumb, which I used to measure it with, and it always improved, or the space became less. It worked really well.“

Male, 15 years

"It ain´t what you don´t know that gets you into trouble. It´s what you know for sure that just ain´t so.”

Mark Twain

Contents

Treatment of large overjet in preadolescents

Studies of treatment effects, cost assessment and patient perceptions
- a comparison of two removable functional appliances

Emina Čirgić

Department of Orthodontics , Institute of Odontology, Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden

ABSTRACT

The **aims** were to compare clinical effectiveness, functional and social discomfort, explore and describe preadolescents' experiences of treatment, and assess the costs of reducing large overjet with an Andresen Activator (AA) and a Prefabricated Functional Appliance (PFA).

Subjects and methods: A multicentre, prospective randomized clinical trial was conducted with patients from 12 general dental practices. Ninety-seven patients with an Angle Class II, Division 1 malocclusion, and an overjet of ≥ 6 mm, were randomly allocated by lottery to treatment with either a PFA or an AA. The study was designed as intention to treat (ITT), and the endpoint of treatment was set to overjet ≤ 3 mm, followed by a 6-month retention period. The PFA and AA group consisted of 57 (28 girls, 29 boys), and 40 subjects (16 girls, 24 boys), respectively, with a mean age of 10.3 years. Overjet, overbite, lip seal, and sagittal molar relationships were recorded before and at the end of treatment, and 1-year post-treatment. One month and 6-months after treatment start, a questionnaire addressing discomfort, perception of treatment need and outcome, was used. Individual interviews focusing on adolescents' experiences of using a removable functional appliance were carried out with 21 adolescents. Direct costs and indirect costs were analysed with reference to ITT (intention-to-treat), successful, and unsuccessful outcomes. Societal costs were described as the total of direct and indirect costs, and did not include retreatments.

Results: No difference in effectiveness could be shown between PFAs and AAs in correcting overjet, overbite, sagittal molar relationship, and lip seal. No difference in experienced functional and social discomfort after 6 months of appliance wear was seen between groups. Participants developed their own strategies of measurement for improvement. The results clearly show that in terms of cost-minimization, PFA is the preferred approach for reduction of large overjet in mixed dentition.

Conclusions: PFAs are as effective as AAs in correcting overjet, overbite, sagittal molar relation, and lip seal. The success rate of treatment with both appliances is, however, low. Thus, the PFA, requiring lower costs, should be used for reduction of large overjet in mixed dentition. No difference could be seen between groups for the experience of functional or social discomfort after 6 months of appliance use. An active involvement of the preadolescents in treatment seems to be necessary, supported by the dentist in future appointments, using overjet measurement as a tool for motivation. Furthermore, efforts should be made by clinicians to listen and understand preadolescents' needs and requirement before treatment start.

Keywords: Orthodontics, preadolescents, large overjet, overjet reduction, removable functional appliance, discomfort, phenomenography, interview, cost assessment.

ISBN: 978-91-629-0059-5 (PDF)

SAMMANFATTNING

Bakgrund: Stort överbett är en vanlig bettavvikelse som förekommer hos cirka 20 procent av den unga befolkningen. Överbett större än 6 mm har i skandinaviska material visat sig förekomma hos cirka 15 procent av tioåriga barn. Konsekvenser av sådana avvikelser medför ökad risk för skador på framtänderna och ett psykosocialt besvärande utseende. Tandskador inträffar oftast innan 10 års ålder och drabbar nästan alltid överkäkens framtänder. En tidigt förebyggande behandling är att föredra både ur ett hälsoekonomiskt perspektiv men också för att minska risken för skador.

Syftet med denna avhandling är att utvärdera och jämföra om behandling med en individuellt framställd tandställning (Andresen aktivator, AA) respektive en prefabricerad tandställning (PFA) ger likvärdig minskning av stora överbett, utforska och beskriva barns upplevelser av behandlingen och bedöma kostnaderna för att minska stora överbett med AA alternativt PFA.

Material och metod: Nittiosju barn med överbett på ≥ 6 mm i 6-14 års ålder, deltog i projektet. Barnen lottades till att antingen behandlas med AA eller PFA. Tandställningen kontrollerades var 4-8:e vecka i minst 6 månader eller tills målet (överbett ≤ 3mm) var uppnått. Barnen fick svara på ett frågeformulär 1- och 6 månader efter påbörjad behandling. Enskilda intervjuer med fokus på barns erfarenheter av att använda tandställningen hölls med 21 ungdomar. Föräldrarna fick svara på ett frågeformulär om tiden och kostnader för att följa med barnet till tandläkaren. Direkta och indirekta kostnader utvärderades med avseende på både lyckade och misslyckade behandlingsresultat. Samhällskostnaderna beskrevs som summan av direkta och indirekta kostnader.

Resultat:

* Likvärdig minskning av stora överbett uppnåddes med AA och PFA
* Båda tandställningarna orsakade lika mycket obehag efter 6 månader
* Barn utvecklade sina egna strategier för att mäta förbättringen
* PFA är billigare än AA vid behandling av överbett hos 6-14 åringar

Slutsatser: Lyckandefrekvensen vid behandling med båda tandställningarna är låg, därför bör PFA, som ger lägre kostnader och ingen avtryckstagning, användas för att minska stora överbett hos 6-14 åringar. Barn bör involveras aktivt i behandlingen med hjälp av tandläkare som använder mätning av överbett som ett verktyg för motivation. Dessutom bör tandläkare lyssna och förstå barns behov och önskan innan behandlingsstart.

PREFACE

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Čirgić E, Kjellberg H, Hansen K. Treatment of large overjet in Angle Class II: division 1 malocclusion with Andresen activators versus prefabricated functional appliances-a multicenter, randomized, controlled trial.
Eur J Orthod 2016; 3 (5): 516-524.

II. Čirgić E, Kjellberg H, Hansen K. Discomfort, expectations and experience during treatment of large overjet with Andresen activator or prefabricated functional appliance, a questionnaire survey.
Acta Odontol Scand. 2017 Jan 2:1-7. [Epub ahead of print]

III. Čirgić E, Kjellberg H, Hansen K, Lepp M. Adolescents' experiences of using removable functional appliances.
Orthod Craniofac Res. 2015; 18: 165-174.

IV. Čirgić E, Kjellberg H, Petzold M, Hansen K. A cost minimization analysis of large overjet reduction with two removable functional appliances based on a randomized controlled trial.
Under review in Eur J Orthod

ABBREVIATIONS

AA Andresen Activator

PFA Prefabricated Functional Appliance

GPs General practitioners

ITT Intention-to-treat

S Successful group- improvement of overjet at every visit

US Unsuccessful group- no improvement of overjet for the last 6 months

T0 Before start of treatment

T1 End of treatment (The endpoint of treatment was set at overjet ≤ 3 mm followed by a 6-month retention period)

T2 1-year post treatment

EGA Eruption Guidance Appliance

DEFINITIONS IN SHORT

Childhood the age span ranging from birth to adolescence.

Preadolescence also known as **pre-teen** or **tween**, is a stage of human development following early childhood and preceding adolescence. It commonly ends with the beginning of puberty, but may also be defined as ending with the start of the teenage years. For example, dictionary definitions generally designate it as 10–13 years.

Adolescence from Latin *adolescere*, meaning "to grow up", is a transitional stage of physical and psychological development that generally occurs during the period from puberty to legal adulthood (age of majority). Adolescence is considered to be the period between ages 13 and 19.

("Puberty and adolescence". MedlinePlus. United States National Library of Medicine.)

INTRODUCTION

Prominent upper front teeth pose a common problem for preadolescents. There are some children with large overjet who are in need of treatment but are too anxious to undergo the procedure of taking dental impressions. Prefabricated functional appliances may be a solution.

Angle Class II Division 1

In order to describe malocclusions, Edward Angle designed a model based on the occlusal relationship of the first molars. Angle´s classification of malocclusion in the 1890s was an important step in the development of orthodontics, suggesting that the upper first molars were the key to the occlusion. Angle Class II malocclusion is described as the distal relationship between the lower and upper dental arches. The lower molar is, thus, distally positioned relative to the upper molar. In Angle Class II Division 1 the maxillary anterior teeth are proclined, and a large overjet is often present (Figure 1).

Aetiology

Angle Class II malocclusion is not a single clinical entity. This discrepancy can result from numerous combinations of skeletal and dental components. Aetiological factors can be hereditary or environmental. Much has been written in the orthodontic literature concerning the nature of Class II malocclusion, suggesting that heredity plays a far greater role than the environment in the development of ”malocclusion” (Smith and Balit 1977, Harris and Johnson 1991, Johannsdottir, Thorarinsson et al. 2005). Among factors, mandibular retrognathism is considered dominant (McNamara 1981, Pancherz, Zieber et al. 1997). Furthermore, abnormalities in both the horizontal and vertical development of the mandible are the most common components of Class II malocclusion (McNamara 1981). However, one should interpret this part of the literature with caution, since according to an orthodontic textbook (Proffit, Fields et al. 2013) only 5 per cent of malocclusions have

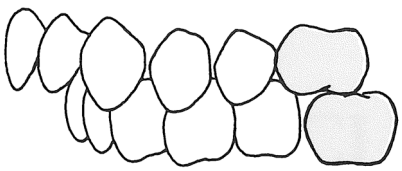

Figure 1. Angle Class II Div 1. Published in Proffit 2013.

a completely known aetiology; the remainder are results of a complex and poorly understood combination of inherited and environmental influences.

Prevalence

The exact prevalence of Class II malocclusion is difficult to determine because of different methods used in previously publish studies, and due to the various ethnic characteristics of the samples (Emine, Lale et al. 2015, Krooks, Pirttiniemi et al. 2016, Silveira, Freire et al. 2016) One can, however, conclude that Angle Class II Div 1 is a common type of malocclusion, and is nearly ten times as common as the Angle Class II Division 2 type with retruded upper incisors (Thilander and Myrberg 1973).

Angle Class II Division 1 malocclusion is reported to affect nearly 25 per cent of 12-year-olds in the United Kingdom (Holmes 1992, Thiruvenkatachari, Harrison et al. 2015), and 15 per cent of 12- to 15-year-olds in the United States (Proffit, Fields et al. 1998). The prevalence in a Scandinavian population was estimated at 10-20 per cent, the higher figure in younger ages (Thilander and Myrberg 1973). However, a frequency as high as 49 per cent of Class II malocclusion has been reported in a Swedish group of 12-13-year-old children (Josefsson, Bjerklin et al. 2007). Large overjet (>6 mm) as a feature of the Class II malocclusions is seen in 14–15 per cent of 10-year-old Scandinavian children (Ingervall, Seeman et al. 1972, Thilander and Myrberg 1973).

Treatment of large overjet

As prominent upper front teeth are a common problem affecting numerous preadolescents, reduction of prominence is one of the most common treatments performed by orthodontists. Preadolescents with large overjet are more likely to experience dental injuries, and in some cases, teeth appearance may cause significant distress (Thiruvenkatachari, Harrison et al. 2013). Therefore, orthodontic treatment is often recommended.

Why should we treat?

A number of studies (Helm, Kreiborg et al. 1985, Dimberg, Arnrup et al. 2015) in recent years have confirmed that severe malocclusion is likely to become a social handicap (Figure 2). The usual caricature of a less gifted individual includes protruding upper incisors (Proffit, Fields et al. 2013). Well aligned teeth and a pleasant smile convey positive status at all social levels and ages, where irregular or protruding teeth convey negative status (Shaw, Rees et al. 1985, Kerosuo, Hausen et al. 1995).

The upper front teeth (incisors) may stick out if the lower lip catches behind them, or due to poor habits (e.g. thumb sucking). Prominent protruding teeth gives the patient an appearance that may be a target for teasing (Shaw, Meek et al. 1980) or bullying (Seehra, Fleming et al. 2011, Seehra, Newton et al. 2011), which may impact the patient's oral health quality of life (Johal, Cheung et al. 2007, Dimberg, Arnrup et al. 2015). When front teeth stick out they are more likely to be injured (Jarvinen 1978, Nguyen, Bezemer et al. 1999). Both increased overjet and inadequate lip seal are considered significant risk factors for dental trauma to the maxillary incisors (Burden 1995).

Figure 2. Preadolescent with large overjet. Published by Kingsley 1881.

Earlier studies have shown little or no gender-based differences with respect to treatment need (Helm 1968, Thilander and Myrberg 1973, Mi, Fan et al. 2003), although there are some exceptions, reporting a higher treatment need in boys (Ingervall, Seeman et al. 1972). Additionally, patients aware of a malocclusion do not always consider the treatment need to be as great as the orthodontist does (Espeland and Stenvik 1991, Mandall, McCord et al. 2000).

Treatment demand was found to be the most powerful predictor of orthodontic treatment need (Taghavi Bayat, Huggare et al. 2016). The findings also suggested a discrepancy in attitudes between professionals focusing on the oral health aspects of malocclusions, and adolescents focusing on aesthetic aspects (Taghavi Bayat, Hallberg et al. 2013). Thus, recommendation for treatment should be a balance between the clinician's risk assessment and the patient's desire for treatment.

When should we treat?

If a child is referred at a young age, the orthodontist is faced with the dilemma of whether to treat the patient early, or to wait until the child is older and provide treatment in early adolescence. Numerous studies concerning treatment timing form a contributing factor to this dilemma.

Early treatment has been suggested to reduce the incidence of trauma to the upper permanent incisors in patients with large overjet and/or incompetent

lip closure (Jarvinen 1978, Burden 1995). The most recent review article investigating early treatment of Class II Division 1 malocclusion showed less incidence of new incisor trauma as the only significant outcome in the early treatment group (Thiruvenkatachari, Harrison et al. 2015). There were no other advantages to providing 2-phase treatment compared with 1 phase in early adolescence. Furthermore, according to a systematic review (The Swedish Council on Technology Assessment in Health Care 2005), most trauma to the upper incisors occur between ages 8 and 14, which speaks for early treatment. However, early treatment for trauma prevention should be initiated soon after the eruption of the permanent incisors (Koroluk, Tulloch et al. 2003). Additionally, it was found that children aged 8 to 11, when early treatment is usually administered, had the highest prevalence of dental trauma, thus orthodontic treatment should preferably start before that age (Caliskan and Turkun 1995, Bauss, Rohling et al. 2004, Oldin, Lundgren et al. 2015).

Early orthodontic intervention has also been suggested in children suffering psychological and social problems related to large overjet (O'Brien, Wright et al. 2003). A few studies concluded that malocclusion has a negative effect on oral health quality of life (Kerosuo, Hausen et al. 1995, Johal, Cheung et al. 2007, Dimberg, Arnrup et al. 2015). However, no studies have been found to support the notion that treatment of large overjet improves quality of life to any great extent. Thus, we cannot be certain if treatment timing has an influence on outcome.

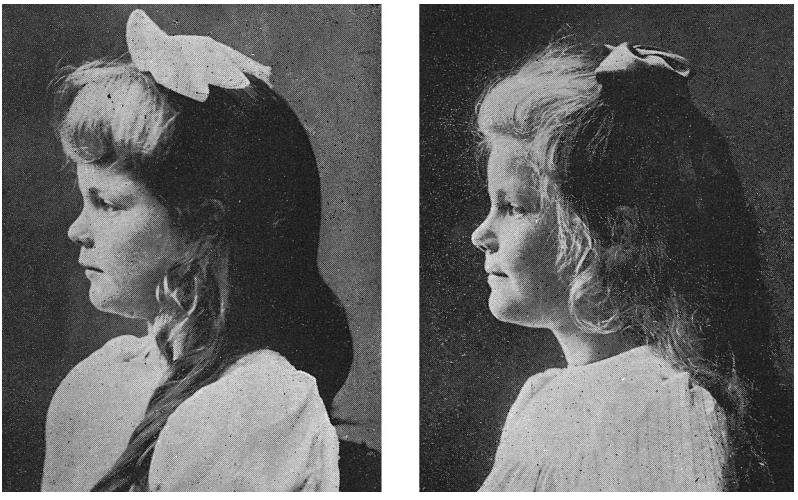

Figure 3. Improvement of the patient's facial profile. Published by Andresen 1914.

How should we treat?

The correction of a Class II Division 1 malocclusion with functional appliances is a common treatment approach in young patients (Casutt, Pancherz et al. 2007). The functional appliance, which can be fixed or removable, shifts the mandible into a protrusive position (Figure 3), generating muscle activity that creates the orthodontic forces (Cohen 1981) needed to correct the sagittal relationship, and aiming to improve the patient's facial profile (Andresen, Häupl et al. 1953, Pancherz 1976).

Removable functional appliances

History

The history of the functional appliance can be traced back to 1879, when Norman Kingsley (Figure 4) introduced the "bite-jumping" appliance.

The monobloc, developed by Robin in 1902, is generally considered the forerunner of removable functional appliances, but the activator developed in Norway by Andresen in the 1920s was the first functional appliance to be widely accepted, becoming the basis of the "Norwegian system" (Ahlgren 1983). Both the appliance and its theoretical principles were improved and extended to Europe with the German school led by Häupl, Bimler, and Balters (Schmuth 1983).

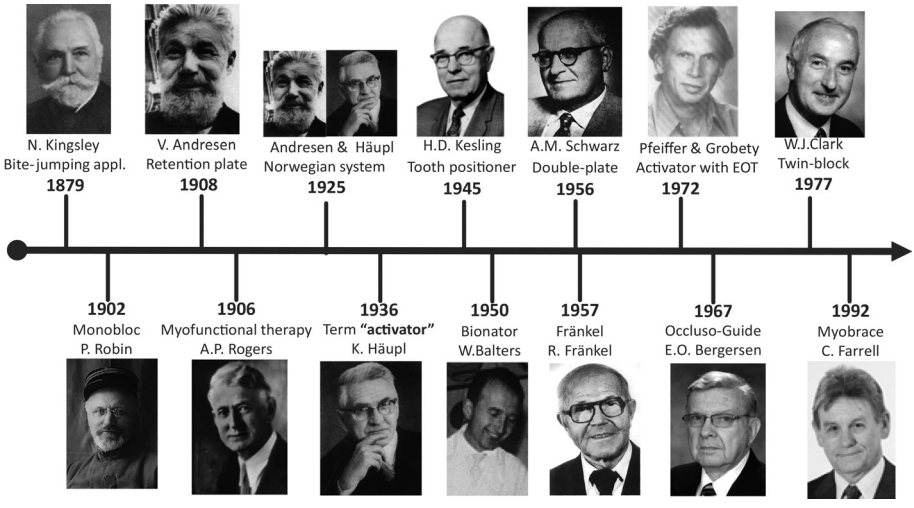

Figure 4. Timeline of removable functional appliances (Burke 2015).

Effects

There is some controversy as to the mode of action of the functional appliances. A functional appliance is by definition an appliance that changes the posture of the mandible both sagittally and vertically. These appliances are capable of changing the position of the teeth, by stimulating the masticatory muscles and soft tissues of the face, producing a distalising force on the upper dentition, and an anterior force on the lower (Woodside 1973, Carels and van Steenberghe 1986, Bishara and Ziaja 1989, Aelbers and Dermaut 1996, Dermaut and Aelbers 1996). These forces are directly or indirectly transferred to the underlying dentoskeletal tissues, resulting in a correction of the malocclusion by improving the molar relationship and reducing overjet. Ahlgren (Ahlgren 1978) indicated that the protractor muscles of the mandible are stimulated during the daytime use of activators, while the retractor muscles are inhibited; these effects are not seen during night-time use. These results are in agreement with the study of treatment effects with Occlus-o-Guide and Andresen activator appliances (Farronato, Giannini et al. 2013). This may be the reason for recommending the use of the appliances both day and night.

Skeletal changes have been said to be brought about by stimulation of condylar growth (McNamara and Carlson 1979, Williams and Melsen 1982, Rabie, She et al. 2003, Araujo, Buschang et al. 2004), as well as by a certain amount of advancement of the glenoid fossa (Birkebaek, Melsen et al. 1984, Vargervik and Harvold 1985, Woodside, Metaxas et al. 1987). On the other hand, a prospective, randomized clinical trial from the United Kingdom strongly suggested that 98 per cent of the occlusal correction was caused by tipping the teeth with an almost negligible effect on the skeletal growth pattern (O'Brien, Wright et al. 2003). This was confirmed in a Cochrane update on treatment of prominent upper teeth (Thiruvenkatachari, Harrison et al. 2013).

Andrésen activator (AA)

The activator (Figure 5) initially developed by Andrésen (Andresen, Häupl et al. 1953), is an acrylic construction customized to both the upper and lower jaws, and the first widely used functional appliance. The appliance is in itself passive, and tooth-borne, being designed to advance the mandible

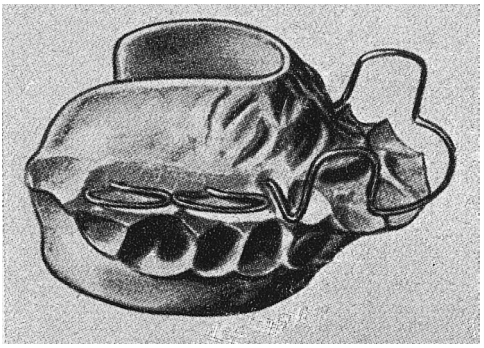

Figure 5. Andresen activator. Published by Andresen 1953.

several millimetres for Class II correction, open the bite 3 to 4 mm, and modify functional patterns by stimulating muscle activity. Because the activator is made with the mandible in a protruded position, the retractor muscles become activated. This results in a posteriorly directed force to the maxilla, and an equally anterior force to the mandible. In some cases expansion of the upper arch is performed prior to activator treatment.

The activator prevents the mandible from sliding backwards, and transfers the forces to the maxilla, which is essentially the anchorage unit for the anteriorly displaced mandible (Andresen, Häupl et al. 1953, Hirzel and Grewe 1974). The literature contains a large number of studies investigating the effects of the activator appliance and responses to treatment (Harvold and Vargervik 1971, Pancherz 1976, Ahlgren 1978, Calvert 1982, Vargervik and Harvold 1985, Ghafari, Shofer et al. 1998, Keeling, Wheeler et al. 1998, Tulloch, Phillips et al. 1998, Wheeler, McGorray et al. 2002, King, McGorray et al. 2003, O'Brien, Wright et al. 2003, Cozza, De Toffol et al. 2004, Cozza, Baccetti et al. 2006).

Prefabricated functional appliance (PFA)

Bergersen (Bergersen 1984) developed a prefabricated elastomeric appliance in 1975, to correct malocclusions. It was called the Eruption Guidance Appliance (EGA), and was a combination of a functional appliance and a tooth positioner (Figure 6). The eruption guidance appliance (EGA) aims to correct sagittal and vertical occlusal relationships concomitantly with alignment of the incisors. The property of the elastomeric material is supposed to induce minor tooth movement during bite closure. The appliance was used with the same indications as most functional appliances, and was easy to prescribe, as it was prefabricated (Bergersen 1985, Janson, de Souza et al. 2004, Janson, Nakamura et al. 2007). Various modifications of the EGA have been presented during the years, and the reported treatment effects were mainly dentoalveolar (Janson, da Silva et al. 2000, Janson, Caffer Dde et al. 2004, Usumez, Uysal et al. 2004). Prefabricated functional appliances (PFAs) have now been used for several years, and their effects have been confirmed (Keski-Nisula, Hernesniemi et al.

Figure 6. The Eruption Guidance Appliance -EGA. Published by Bergersen 1984.

2008, Myrlund, Dubland et al. 2015, Nilsson, Shu et al. 2016), suggesting that Angle Class II corrections can be achieved with a PFA, and that it appears to have mostly dentoalveolar effects (Das and Reddy 2010)

This appliance is recommended to be worn actively about two hours per day, and passively, while sleeping, to obtain optimal results (Kleinerman and Bergersen 2011, Migliaccio, Aprile et al. 2014).

Patient-centred outcomes

There is an acceptance that patient-centred measures should be included in clinical trials, and there is a growing recognition that clinical research needs to define and focus on outcomes of medical care, which are important to patients, that is "patient-centred" outcomes (Curtis 1998). Most outcomes used in orthodontic research are concerned with measuring morphologic changes of treatment, and do not reflect the patient's perspective (Tsichlaki and O'Brien 2014). Although the adoption of randomized clinical trial (RCT) methodology in orthodontic research is increasing, (Harrison 2003) reported outcomes appear to be mostly relevant to clinicians, not patients. In orthodontics, cephalometric findings should no longer be the major determinant of treatment goals. This highlights the need for studies to increase the understanding of how removable functional appliances are experienced and how they influence a patient's life and quality of life.

Discomfort

Only a few studies have evaluated pain, discomfort and acceptance associated with functional appliances. Orthodontic patients experience pain and discomfort to a varying degree during the course of treatment. An adaptation occurs during the first 3 to 5 days after placement of the appliance. Patients, who had a higher personal perception of the severity of their malocclusion and internal control orientation, seemed to adapt faster and have less pain (Stewart, Kerr et al. 1997, Kavaliauskiene, Smailiene et al. 2012). Acceptance of the orthodontic appliances, and treatment in general, may be predicted by the amount of initial pain and discomfort experienced (Sergl, Klages et al. 1998). A significant reduction in the number of complaints was observed between 2 and 7 days after insertion of the appliance. The type of appliance had an effect on speech and swallowing, and there was a relationship between complaints and the acceptance of the appliance, as well as between lack of confidence and compliance with treatment. The first visits to the orthodontist after insertion of the appliance is suggested to be after 3-4 weeks in order to

encourage and motivate patients during the early and difficult period of the treatment (Sergl, Klages et al. 2000).

In interceptive orthodontics, the fabrication of most oral appliances requires impressions taken of the patient's teeth. Dental impression is often considered uncomfortable, and has been stated to be the most unpleasant experience during orthodontic treatment (Hacker, Heydecke et al. 2015, Burhardt, Livas et al. 2016). Regarding children's anxiety and discomfort it was concluded that children benefit from beginning an appointment with an easier procedure, working up to a more difficult one (Kaakko, Horn et al. 2003). Furthermore, gagging in orthodontic patients may be a barrier to patient care, and could disturb treatment. Thus, treatment where impressions are not needed might be an advantage when treating young patients with large overjet aiming to reduce the risk for maxillary incisor trauma.

Compliance

The success of treatment with a removable functional appliance is dependent on patient compliance (Brattstrom, Ingelsson et al. 1991, Nanda and Kierl 1992, Bartsch, Witt et al. 1993). To objectively assess patient compliance in treatment with removable functional appliances, and the effect of possible influential factors, is challenging. Several studies have been performed to investigate and explain the main reasons for poor compliance (Slakter, Albino et al. 1980, Gross, Samson et al. 1988). Objective measures are necessary since patient compliance is a highly variable issue. Recently, there have been studies showing that patients only fulfilled 50-60 per cent of the orthodontist's requirements (the 15 hours/day prescribed) with respect to wear time of the orthodontic appliance (Sahm, Bartsch et al. 1990, Schafer, Ludwig et al. 2015). Younger patients had significantly longer wear time than older, and a significant increase in time wear was found when patients had private insurance covering treatment costs (Schafer, Ludwig et al. 2015). Additionally, according to Trulsson et al. (2004) younger children need greater parental involvement for compliance than older children, who seem to have a higher degree of internal motivation for treatment, and less need for parental support. It has also been suggested that if treatment compliance cannot be ensured through a parent's enthusiastic involvement, it seems better to delay treatment until the child is older and more motivated (Trulsson, Linlav et al. 2004).

A patient's experience and description of orthodontic treatment need is important. Psychological factors may influence a patient's perception of their malocclusion as well as the treatment plan. It is difficult to know or predict how a patient will view his or her individual situation. Our knowledge is

generally a matter of information from different sources by means of which we may gain an understanding of how people conceive various aspects of their world (Marton 1981). We can also interpret how people conceptualize their world by studying their behaviour under certain controlled conditions, or in everyday life (Marton 1986). There are several research approaches e.g. questionnaires, interviews, etc. that can help in gaining some insight into how a patient perceives a malocclusion, which may aid orthodontists in assessing the patients more accurately.

There is little evidence concerning the relative effectiveness of functional appliances in relation to patients' experiences and perceptions of these treatment modalities. Further, well-designed clinical trials assessing the relative merits of both clinician- and patient-centred outcomes are needed (Pacha, Fleming et al. 2015).

Treatment success rate and stability of successful treatments

Good patient compliance was suggested as the only predictive factor for the success rate of activator treatments (Casutt, Pancherz et al. 2007), and the significant disadvantage of removable functional appliances was the onus of patient compliance, with a success rate to complete treatment reported as not higher than 66 per cent (O'Brien, Wright et al. 2003). After activator treatment, 40 per cent of the successful subjects required no further orthodontic treatment (Rizell, Svensson et al. 2006, Casutt, Pancherz et al. 2007), and a follow-up study on functional appliances by Sepanian et al. (Sepanian, Paulsson-Björnsson et al. 2014) showed a 35 per cent success rate. Bondevik (1991) reported, however, that only 18 per cent of the patients treated with an Andresen headgear activator achieved satisfactory results (Bondevik 1991), while Ahlgren (1972) reported 75 per cent success with Andresen activator (Ahlgren 1972).

Several factors have been proposed to explain relapse and the variability seen in treatment stability with functional appliances (Drage and Hunt 1990, Feldmann, Lundstrom et al. 1999, Antonarakis, Kjellberg et al. 2013). A major factor contributing to stability is thought to be the growth pattern of the patients (Ormiston, Huang et al. 2005). On the other hand, large changes during treatment in molar and canine relationships were the only two factors found to be positively associated with relapse, but with limited evidence (Wins, Antonarakis et al. 2016). Prediction after orthodontic treatment is difficult, as dentition constantly changes throughout life, with or without orthodontic treatment (Bondevik 1998, Thilander, Persson et al. 2005, Bondemark, Holm et al. 2007, Thilander 2009).

Cost effectiveness

Dental health care in Sweden is free of charge for those under twenty, and roughly one-third of all children and adolescents in Sweden are offered cost-free orthodontic treatment (Bergstrom and Halling 1996, The Swedish Council on Technology Assessment in Health Care 2005). Ineffective treatments with or without low compliance that result in discontinued treatments are costly to society and should be avoided. (Backstrom 1985, Follin, Kahnberg et al. 1993, Hedlund and Feldmann 2016). Cost-effective healthcare requires a valuation of the economic effects of the intervention (Kumar, Williams et al. 2006). A health-economic evaluation is characterized by the relationship between costs (inputs) and consequences (outputs), when different diagnostic or therapeutic options are considered. Four main techniques are available: cost-minimization analysis, cost-effectiveness analysis, cost-utility analysis, and cost–benefit analysis (Drummond, O'Brien et al. 1997, Aguiar-Ibanez, Nixon et al. 2005). Economic assessments with a societal perspective comprise calculations of direct and indirect costs. Direct costs are those related to diagnostic or treatment interventions, whereas indirect costs are the loss of production due to absence from work, travel expenses, and so forth. Societal costs are expressed as the sum of direct and indirect costs.

Orthodontic treatment should, therefore, depend both on clinical skills and cost effectiveness. A recent systematic review highlighted the need for orthodontic studies where both economic and clinical outcomes are presented (Sollenius, Petren et al. 2016).

Level of evidence

The trend in health care for the last few years has been evidence-based treatment, i.e. the selected method should be chosen on the basis of the evidence that it is the most appropriate approach to the patient's problem; the higher the level of evidence, the easier the decision.

Identifying the criteria associated with success, failure, and stability is important, and a biased sample makes this difficult. One important way to control bias in evaluating treatment outcome is to be sure that all subjects that were supposed to be treated (ITT) were included in the study. For this reason, the gold standard for assessing clinical procedures is the randomized controlled trial (RCT), in which patients are randomly assigned to alternative treatment procedures (Figure 7). The advantage of this method is that random assignment, if the sample is large enough, should result in an even distribution of all variables in the groups.

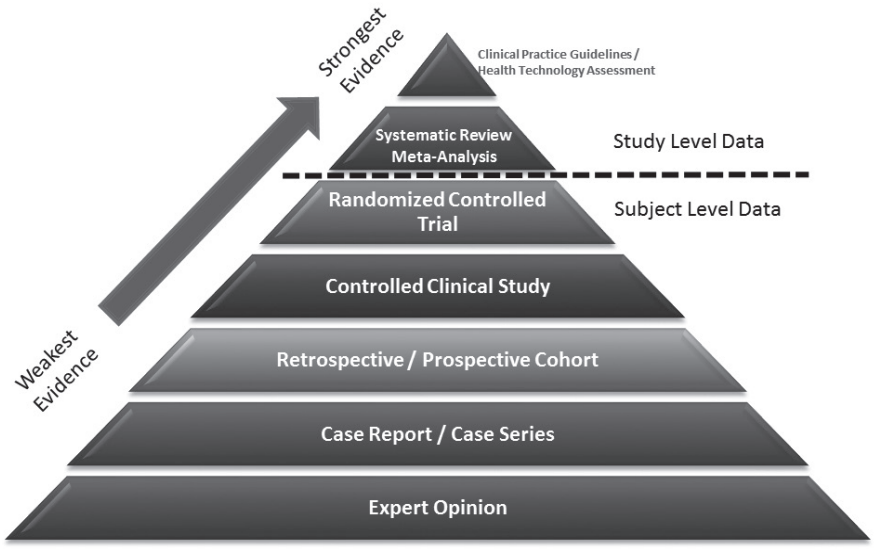

Figure 7. A hierarchy of the evidence quality.

The level of evidence is based on the quality of the studies. One system of defining the level of evidence is The GRADE approach (Atkins, Best et al. 2004) used in e.g. Cochrane Collaboration.

The GRADE evidence quality:

High	Further research is very unlikely to change our confidence in the estimate of effect
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Very low	We are very uncertain about the estimate

What does evidence say about treatment of large overjet with removable functional appliances?

So what do we know?

Why, when, and how should we treat large overjet?

- Providing early Class II treatment with functional appliances reduces incisal trauma- *moderate level of evidence* (Thiruvenkatachari, Harrison et al. 2013)

- Orthodontic treatment improves oral health quality of life - *moderate level of evidence* (O'Brien, Wright et al. 2003, Dimberg, Arnrup et al. 2015)
- Reduction of the incidence of trauma is the only reason for treatment in early adolescence - *moderate level of evidence* (Thiruvenkatachari, Harrison et al. 2013, Thiruvenkatachari, Harrison et al. 2015).
- Early treatment for trauma prevention should start soon after the eruption of the permanent incisors- *moderate level of evidence* (Koroluk, Tulloch et al. 2003, Oldin, Lundgren et al. 2015).
- Teasing and bullying is associated with large overjet -*low level of evidence* (Shaw 1981, Seehra, Fleming et al. 2011)
- Treatment of large overjet increases self-esteem- *moderate level of evidence* (O'Brien, Wright et al. 2003)
- A removable functional appliance corrects large overjet in the mix dentition - *high level of evidence* (Tulloch, Proffit et al. 1997, O'Brien, Wright et al. 2003).
- Reduction in overjet is achieved mainly by tooth movement with minimal and unpredictable skeletal change– *moderate level of evidence* (Koretsi, Zymperdikas et al. 2015, Pacha, Fleming et al. 2015).
- The choice of functional appliance when compared to the Twin Block appliance does not result in advantageous effects- *high level of evidence* (Thiruvenkatachari, Harrison et al. 2013).
- Large changes in molar and canine relationships during treatment were positively associated with relapse- *low level of evidence* (Wins, Antonarakis et al. 2016).
- Most of the outcomes used in orthodontic research do not reflect patient perspectives- *moderate level of evidence* (Tsichlaki and O'Brien 2014).
- The acceptance of orthodontic appliances may be predicted by initial pain and discomfort experienced- *moderate level of evidence* (Sergl, Klages et al. 1998, Sergl and Zentner 1998, Sergl, Klages et al. 2000)
- Patients fulfil 50-60 per cent of the recommended wear time for the orthodontic appliance - *moderate level of evidence* (Sahm, Bartsch et al. 1990, Schott and Ludwig 2014, Schafer, Ludwig et al. 2015)
- Unsuccessful and discontinued treatments due to low compliance are costly to society and should be avoided- *low level of evidence* (Follin, Kahnberg et al. 1993, Hedlund and Feldmann 2016).

One should, however, remember that absence, or lower levels of evidence do not necessarily mean that treatment is not working or is not effective. It is the evidence to support the treatment that is lacking, whereby we then must rely on recognised clinical experience until new studies have addressed the topic or area. The studies in this thesis aim to raise the level of evidence for some of these topics.

AIMS

The overall aim of this thesis was to explore if a prefabricated functional appliances (PFA) could be used to treat patients with large overjet.

The aims of the papers are as follows:

PAPER I

To compare the clinical effectiveness between a Prefabricated Functional Appliance (PFA) and a slightly modified Andresen Activator (AA) in reducing large overjet.

PAPER II

To investigate the amount of functional and social discomfort experienced after 1 and 6 months of appliance wear, comparing a slightly modified Andresen Activator (AA) and a Prefabricated Functional Appliance (PFA).

To investigate patient perception of treatment need, appliance acceptance, expectations of treatment influence on oral health, value of dental aesthetics, and information concerning treatment procedures.

PAPER III

To explore and describe adolescents' experiences of treatment with removable functional appliances for reduction of large overjet.

PAPER IV

To assess and relate the societal costs of reducing large overjet with a Prefabricated Functional Appliance (PFA), or a slightly modified Andresen Activator (AA), using a cost-minimization analysis.

PATIENTS AND METHODS

There are different perspectives and methods used. Both quantitative and qualitative methods have been used to fulfill the overall aim of this thesis. All the studies were performed in Gothenburg, Sweden. The methods and results are described in detail but here briefly summarized in Table 1.

Table 1. Overview of the four papers in this thesis

Paper	Study design	Participants	Data collection	Data analysis
I	Quantitative Multicenter RCT	Preadolescents 10.3 y (7-14) n= 97	Treatment outcomes	Statistical
II	Quantitative Qualitative	Preadolescents 10.3 y (7-14) n= 67 (1 months) n= 44 (6 months)	Questionnaires	Statistical Descriptive Content
III	Qualitative	Adolescents 13.2 y (11-15) n= 21	Individual interviews	Phenomenography
IV	Quantitative Multicenter RCT	Preadolescents 10.3 y (7-14) n= 97 Parents n= 178	Cost-minimization	Statistical

Subjects (Paper I-IV)

The total sample of subjects in papers I-IV were consecutively recruited from 12 public general dental practices in Gothenburg, Region Västra Götaland, Sweden, from 2007-2010.

The following inclusion criteria were applied:

- 6–14-year-old patients with erupted central incisors
- Angle Class II division 1
- Increased overjet ≥6 mm, or less with lip incompetence
- No previous orthodontic treatment

Patients with crossbite, severe crowding, agenesis, other malocclusions, and syndromes were excluded.

Orthodontists from the Orthodontic Clinic in Gothenburg recruited patients during consultations at the general dental clinics. Patients that

fulfilled the above inclusion criteria were invited to participate in the study, and informed written consent was obtained from their parents. The patients were randomly allocated to two treatment groups.

Paper III

The first 50 patients in the ongoing study were asked to take part in an individual interview. The subjects were to have been treated for at least 6 months.

Paper IV

For calculating indirect costs an additional 178 subjects were recruited from the same 12 public general dental practices in Gothenburg, Region Västra Götaland, Sweden, during 2015 to match patients from the randomized study.

The following inclusion criteria were applied:

- Legal guardians or parents were to accompany the children to the orthodontic treatment
- Orthodontic treatment with a removable appliance was to be administered

Methods

Randomization

The study was designed as intention to treat (ITT), and patients were randomly allocated to treatment with either a PFA or an AA (Figure 8). At every clinic

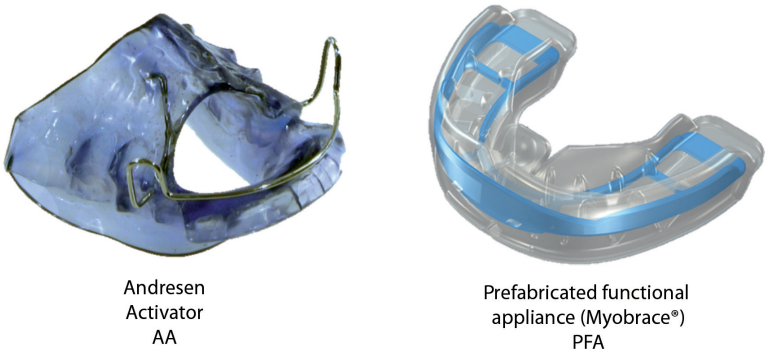

Figure 8. Andresen activator (AA) standardized but custom-made, slightly modified AA with opening in the front to make it easier for mouth breathing. Prefabricated functional appliance (PFA; Myobrace®,Myofanctional Research Co, Australia).

two envelopes were available, one for girls, and one for boys, each with 5 AA and 5 PFA notes. If all notes were used, 240 preadolescents would have been available for participation in the study.

Sample size calculation

According to a sample size analysis, 38 patients per group were required to obtain adequate power (80 per cent, at a significance level of $P < 0.05$, with an SD of 1.3, and with the loss of 10 patients), based on a clinically significant difference of 1mm in overjet reduction between the study groups.

Intervention - appliances

The AA was a standardized but custom made, slightly modified activator with a front opening for mouth breathing. The acrylic in the lateral segments was removed to allow eruption of the posterior teeth. A passive maxillary labial bow was used to aid anterior retention, and to retrocline the maxillary incisors if proclined. The construction bite was taken in an edge-to-edge incisal position. All AAs were made at the same orthodontic dental lab according to a given prototype (Figure 9). The general dentist performed adjustments of the AA only for erupting teeth at recalls.

The PFA (Myobrace®, Myofunctional Research Co, Australia) was available in seven sizes. The size of the appliance was chosen according to the manufacturer's recommendations. All PFAs were ordered from the same company (Figure 10). The PFA needed no adjustment by the general dentist.

The patients were instructed to use the appliances at night, and 2 hours during the day i.e. 12-14 hours in all. Daytime wear could be divided into periods of at least 30 minutes. An initial check-up was performed after 4 weeks, with subsequent visits every 6-8 weeks. When the overjet had been reduced to ≤3 mm, the treatment was regarded as successful, and the patient

Figure 9. Slightly modified Andresen Activator (AA) with a front opening for mouth breathing.

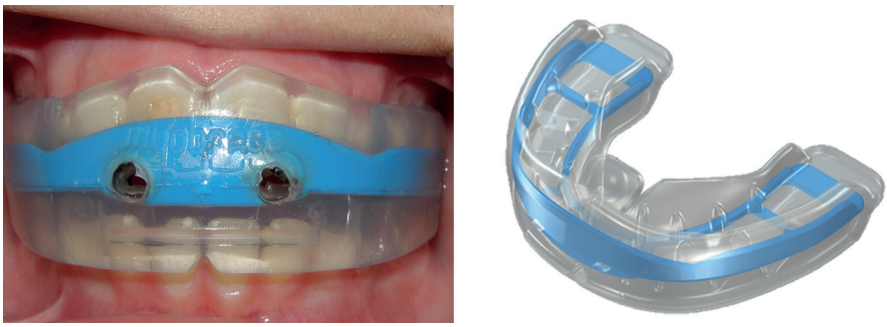

Figure 10. Prefabricated Functional Appliance (PFA) was available in seven sizes.

then continued to wear the appliance as a retainer only at night, for 6 months.

The treatment was classified as unsuccessful if there was no additional reduction in overjet for a period of 6 months, and/or if the patients refused to use the appliance or keep appointments.

Timeline for treatment observations:

T0 before start of treatment

T1 at the end of treatment (The endpoint of treatment was set to overjet ≤3 mm followed by a 6-month retention period)

T2 1-year post treatment

Post retention follow-up: all cases were observed 4 years post retention.

Measurements and calibration (Paper I)

Twelve general dental clinics at the Public Dental Health Services, Region Västra Götaland, were involved in the study. At each clinic one general dentist, with a special interest in orthodontics, treated patients according to a standardized protocol. The 12 general practitioners involved in the study, as well as the 6 consulting orthodontists, were calibrated in measuring overjet, overbite, and classifying the occlusion according to Angle. The Orthodontic Clinic in Gothenburg, Sweden coordinated the study, and general practitioners treated the patients at their clinics.

The following parameters were recorded and defined as:

Overjet (mm): distance between the incisal edge of the most labial maxillary central incisor, and the corresponding lower incisor in a retruded position (RP). Distances were rounded off to the nearest 0.5 mm.

Overbite categorized as: normal (0–4 mm), deep (≥5 mm) with or without palatal impingement, open (<0 mm).

Molar relationship, according to Angle: Class I, ½ Class II (the cusps of the upper first molar occluded over the cusps of the mandibular first molar) and Class II. Class II also refers to subjects with a unilateral deviation.

Overjet, overbite, and molar relationship were recorded at the following stages: T0, T1, and T2.

Lip seal: yes or no; was recorded at T0 and T1.

Questionnaire (Paper II)

To assess the amount of functional and social discomfort experienced during a short (1-month), and long (6-month) period of appliance wear, a questionnaire was prepared. The questionnaire was designed and tested by experienced orthodontists at the Orthodontic Clinic in Gothenburg, Sweden.

The questionnaire consisted of 13 items divided into 3 categories; open questions, questions with response categories, and questions with a rating scale (VAS). The questions focused on: patient perception of treatment need, initiation and expectations of treatment outcome, dental aesthetics, problems regarding appliance use, and information received before treatment. Questions also covered the elements of tension or pressure of the appliance, teeth sensitivity, overall oral pain, speech impairment, swallowing difficulties, oral constraint, and lack of confidence in public (See Appendix).

The questionnaires were handed to patients at ordinary check-ups, one and six months after start of treatment. They were completed at the clinic or at home assisted by parents. The questionnaires were then sent by prepaid mail to the first author (EC). All questionnaires were filled in anonymously. Information from the questionnaires was transferred to an Excel spread sheet (Microsoft Office Professional plus 2013).

Interviews (Paper III)

Individual interviews with a phenomenographic approach were carried out 6 months after the start of treatment. Within phenomenography interviews are common as a means of data collection. The main outcomes of phenomenographic research are descriptions of differences and similarities in conceptions of phenomena in the surrounding world (Marton 1986, Patton 1990, Sjöström and Dahlgren 2002). The phenomenon in this study was the adolescent's experience of the treatment with a removable functional appliance for reduction of large overjet.

Pilot interview

Pilot interviews, both individually and in focus groups, took place. The first author of the study (EC) carried out the interviews, with one of the co-authors (ML) as observer and co-interviewer. The experience of the pilot interviews was that the individual interviews provided more information than the focus group. Adolescents appeared shy and uncomfortable talking about removable appliances in groups, hence, we chose to continue with individual interviews. The findings and participants from the pilot interviews were not included in the study.

Data collection of interviews

Participants were interviewed individually by the first author (EC), and were recorded. The main open research question of the interview was: "*Can you please tell me about your experiences of your removable appliance?"*

Each interview lasted an average of 30 minutes, with a range of 15–50 minutes. The interviews took place at the Orthodontic Clinic in Gothenburg, Sweden.

Cost assessment (Paper IV)

The cost-minimization analysis included the 1-year follow-up (Paper I), and was partly based on a questionnaire survey where data was collected with respect to travel time and costs, and also included the national identification numbers of the parents accompanying their child to orthodontic treatment.

Cost measures

Direct costs included chair time during the treatment and retention period, as well as material costs. Chair time costs comprised dental equipment and disposable items, premises, cleaning, maintenance, and staff salaries, etc. All estimates of chair time costs were calculated in Swedish currency, at SEK 2000 (€ 212) per hour for a general practitioner according to the price list for general dentistry of the Public Dental Service (Folktandvården) in the Västra Götaland region. In addition, the number of appointments, both scheduled and emergency appointments and cancellations, were noted. Material costs (i.e. laboratory invoices and fees for repairs) were calculated according to the laboratory price list (TIC DPNova) for 2015.

Indirect costs, i.e., loss of production when a parent was on leave of absence to accompany their child, were estimated as loss of income (salary plus employer charges to social insurance and collectively negotiated private pension schemes).

We conducted an additional questionnaire survey to collect data on travel time and costs, as well as the national identification numbers of parents accompanying their children to orthodontic treatment, at the same general dental clinics as in the main study. National identification numbers were sent to the Swedish National Bureau of Statistics (http://www.scb.se) where they were matched with a longitudinal integration database for social insurance and labour market studies (LISA by Swedish acronym). The database presently contains annual registers, and includes all registered residents in Sweden, 16 years of age or older. Outcomes from LISA provided the individual annual wages of the parents in SEK for 2013. Since the Consumer Price Index remained the same during the period 2013-2015, no adjustment for changes in cost of living was made. The average findings from the questionnaires and the LISA database are summed up in Table 2.

The sum of direct and indirect costs was defined as 'societal costs'. The cost analysis was based on the intention-to-treat (ITT) principle, i.e. the analysis included data for costs of successful (S) and unsuccessful (US) cases. All costs were in 2015 prices, and expressed in Euros (€), SEK 100 = €9.44 at a mean currency value (www.xe.se).

Cost-minimization analysis

The cost-minimization analysis (CMA) was considered as follows:

CMA = Societal costs divided by the number of patients in the ITT, S and US groups, respectively.

Follow-up and retreatment

Retreatment was monitored during the long-term follow-up period of 4 years.

Table 2. The average indirect costs in euros (€), and average duration based on a questionnaire survey for parents (n= 178) accompanying their child to orthodontic treatment. Loss of income means salary plus employers' costs for social insurance and collectively agreed private pension plans.

Loss of income	35 € / hour
Absent from work:	69 minutes
- Appointment duration	20 minutes
- Travelling time duration	49 minutes
Travel costs	6 € / visit

Statistical analysis (Paper I, II, IV)

Statistical analyses were performed in SPSS for Windows 22.0 (SPSS, Inc., Chicago, Illinois, USA). P-values less than 0.05 were considered statistically significant. In the analysis, the total sample was considered as the ITT group, a successful group including participants who achieved an overjet ≤3 mm at end point, and an unsuccessful group comprising participants discontinuing treatment, or not reaching the end point of the treatment. Parallel analyses were carried out in the three groups. If no significant differences were found between the PFA and AA group these 2 groups were merged and analysed as one.

Changes between the groups

- Chi-square and Fisher's exact tests for categorical variables
- Independent t-tests for continuous variables
- Mann–Whitney's U-test for continuous variables was used in parallel to t-tests due to not symmetric distributions of data and limited sample sizes.

Only in case of discrepancies in significance between the t-test and Mann–Whitney U-test, this was reported.

- Poisson distribution was assumed for count data

Changes within individuals over time during treatment

- A non-parametric Wilcoxon Signed Ranks
- McNemar Test

Responses from the rating scales (VAS) were divided into three equal segments: low (1), moderate (2), and high (3), and were used to determine the intensity of the problem as low, moderate, or high. In order not to affect results, borderline cases were summarized and divided equally between adjacent segments. In case of odd numbers of borderline answers the last mark was distributed to the segment that would least influence the result.

Broken appointments and cancellations were not included in the cost-minimization analysis.

Qualitative analysis (Paper III)

The interviews were transcribed verbatim and analysed according to a phenomenographic approach (Lepp and Ringsberg 2002, Sjöström and

Dahlgren 2002). The analysis was carried out according to Alexandersson's four steps (Den 1994). At the initial stage, all transcribed interviews were carefully read several times to gain a general idea of the data. The second stage was dedicated to finding similarities and differences in the data. At the third stage, statements were classified into descriptive categories of conceptions. In the fourth and final stage, categories and subcategories were defined and emerged, all describing the adolescent's experience of using a removable appliance.

To ensure reliability in qualitative research, examination of trustworthiness is crucial. The categories should represent the participants' perceptions, and not only a construction of the researcher (Marton 1981, Sandelowski 1986, Krefting 1991, Kvale 1996, Shenton 2004). To ensure a truthful data analysis the two co-examiners independently assigned quotations to the correct subcategory. Agreement was almost unanimous.

Ethical approval

The Research Ethics Committee of the Sahlgrenska Academy at the University of Gothenburg, Sweden approved all papers I-IV (Dnr: 437-07), and the guidelines of the Declaration of Helsinki were followed (Association 2013). Written and verbal information was given to the participants and parents. A signed informed written consent was obtained from the parents prior to entering the trial.

This trial was registered at "FoU i Sverige" (http://www.fou.nu/is/ sverige), registration number: 97131.

RESULTS

Treatment effects - Paper I

Participant flow

Figure 11 illustrates the flow of participants through the study. It also shows data loss. During the period 2007-2010, 105 patients agreed to participate in the study. Eight patients were excluded for various reasons. The PFA and AA groups consisted of 57 subjects (28 girls, 29 boys), and 40 subjects (16 girls, 24 boys), respectively.

Baseline findings

No significant differences in age or gender were found between the PFA and the AA groups (Figure 12), and the mean age was 10.3 years (SD 1.64; range 7 14 years) at the start of treatment (T0). There were no statistically significant differences in overjet, overbite, lip seal, or molar relationship at T0 between

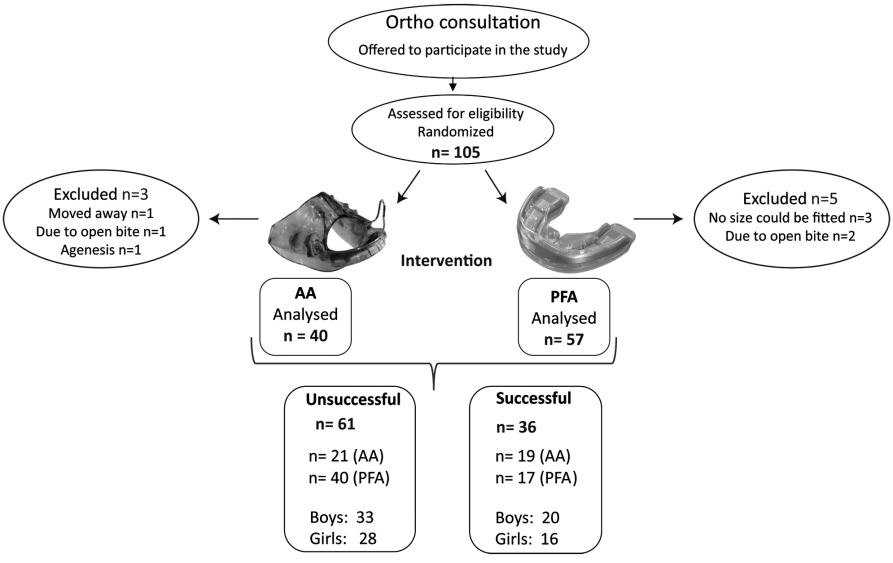

Figure 11. Flow chart of the participants in the study. The unsuccessful group (US) was defined as no improvement of overjet during the last 6 months. Improvement of overjet at every visit was defined as the successful group (S). AA, Andresen activator; PFA, prefabricated functional appliance.

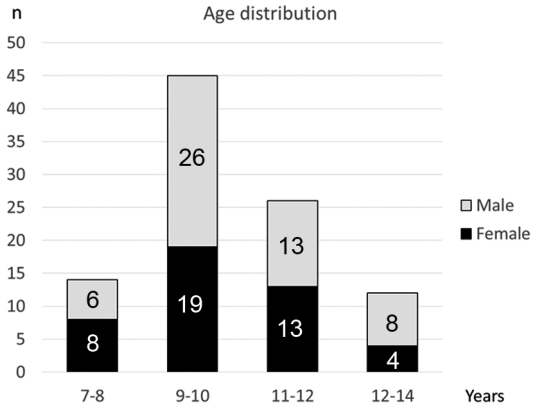

Figure 12. Participant age and gender.

the 2 treatment groups. Gingival impingement was found in 40 per cent of participants, PFA group with 40 per cent, and 37 per cent for the AA group at T0.

Outcomes

Overjet and sagittal molar relationship

No statistical differences were seen in overjet reduction between the AA and PFA groups during the total observation period (T0-T2) as shown in Table 3.

The improvement in molar relationship was comparable for the AA and PFA groups in the ITT and successful cases during the total observation period (T0-T2). Among the unsuccessful cases only very few subjects improved in the sagittal molar relationship.

Table 3. Overjet (mm) for the AA and PFA groups before treatment (T0), after end of the treatment (T1) and 1-year post treatment (T2). ITT, intention to treat; US, unsuccessful group; S, successful group; AA, Andresen activator; PFA, prefabricated functional appliance.

		PFA group			AA group			
		Mean	SD	Range	Mean	SD	Range	P-value
Overjet (ITT)		**PFA (n= 57)**			**AA (n= 40)**			
	T0	8.4	1.83	6.0-18.0	8.9	1.30	6.5-11.5	0.158
	T1	6.2	2.39	2.0-11.0	5.6	2.66	0.5-10.5	0.228
	T2	6.5	2.26	3.0-12.0	6.6	2.72	2.0-12.0	0.772
Overjet (US)		**PFA (n= 40)**			**AA (n= 21)**			
	T0	8.6	2.04	6.0-18.0	9.5	1.22	7.0-11.5	0.073
	T1	7.4	1.76	4.0-11.0	7.7	1.62	4.0-10.5	0.419
	T2	7.3	2.07	3.0-12.0	8.6	1.98	5.0-12.0	***0.026***
Overjet (S)		**PFA (n= 17)**			**AA (n= 19)**			
	T0	7.9	1.13	6.0-9.5	8.2	1.07	6.5-10.5	0.486
	T1	3.5	1.08	2.0-5.0	3.2	0.96	0.5-5.0	0.406
	T2	4.5	1.22	3.0-8.0	4.5	1.51	2.0-8.5	0.960

Overbite and lip seal

Overbite decreased significantly in the ITT group between T0-T1-T2. An improvement was seen in 34 per cent of the group and only 3 per cent worsening. A relapse was present in 11 per cent of the cases and 13 per cent had self-improvement of overbite at T2.

At the end of treatment (T1) improvement was seen in 86 per cent of the successful cases with no worsening. A relapse was present in 25 per cent and 5 per cent had self-improvement of overbite at T2.

In the analysis of overbite changes, the AA and PFA groups were merged into one, as no significant differences in overbite change between these two groups were found. No significant difference was found between T1 and T2.

At the baseline (T0) 88 per cent had no lip seal in ITT group that improved in 61 per cent at the end of treatment (T1) with only 3 per cent worsening. Lip seal improved in both the AA and PFA groups. No significant differences between groups were found, and subsequently the groups were merged. At the end of treatment all successful cases improved.

Success rate and treatment time

Successful treatment outcomes (overjet ≤ 3 mm) were seen in 37 per cent of subjects. No statistically significant differences in success rate, gender, age, or treatment time was found between the PFA and the AA groups (Figure 11, Table 4, Table 5). The mean treatment time was 1.30 years, with no statistically significant difference between the AA (1.50 years SD 0.70), and PFA (1.20 years SD 0.60) groups in ITT cases.

Table 4. Success rate for the AA and PFA group at the end of treatment (T1). Success is defined as achieved overjet ≤ 3mm. P-value for differences in success rate between genders within groups. AA, Andresen activator; PFA, prefabricated functional appliance.

	PFA (n=57) Female (n= 28) Male (n= 29)	**AA** (n=40) Female (n= 16) Male (n= 24)	**Total** (n=97) Female (n= 44) Male (n= 53)
Success rate	P=0.565*	P= 0.520*	P=0.847*
Total	17(30%)	19 (47%)	36 (37%)
Female	7 (25%)	9 (56%)	16 (36%)
Male	10 (34%)	10 (42%)	20 (38%)

*Difference between genders within groups tested with Fisher´s Exact test. No significant difference in success rate between PFA and AA groups, gender, age, or treatment time was seen.

Table 5. Treatment time (years) for the AA and PFA groups at the end of treatment (T1). ITT, intention to treat; US, unsuccessful group; S, successful group; AA, Andresen activator; PFA, prefabricated functional appliance.

Treatment time (ITT)	Mean	SD	Range	95% confidence interval	
PFA (n=57)	1.21	0.61	0.30 - 3.00	1.05 - 1.38	
AA (n= 40)	1.43	0.67	0.44 - 3.36	1.22 - 1.64	
Total (n=97)	1.30	0.64	0.30 - 3.36	1.17 - 1.43	
Treatment time (US)					
PFA (n=40)	1.04	0.53	0.30-2.62	0.87-1.21	
AA (n= 21)	1.26	0.59	0.44-2.57	0.86-1.39	
Total (n=61)	1.07	0.55	0.30-2.62	0.93-1.21	P<0.001
Treatment time (S)					
PFA (n=17)	1.62	0.61	0.89 - 3.00	1.31 - 1.94	
AA (n= 19)	1.76	0.59	0.99 - 3.36	1.48 – 2.05	
Total (n=36)	1.70	0.59	0.89 - 3.36	1.50 - 1.90	

Discomfort and expectations - Paper II

Participant flow

Sixty-seven patients (69%) completed the 1-month questionnaire, and 44 (45%) completed the 6-month form, as shown in Figure 13. All questionnaires were filled in anonymously.

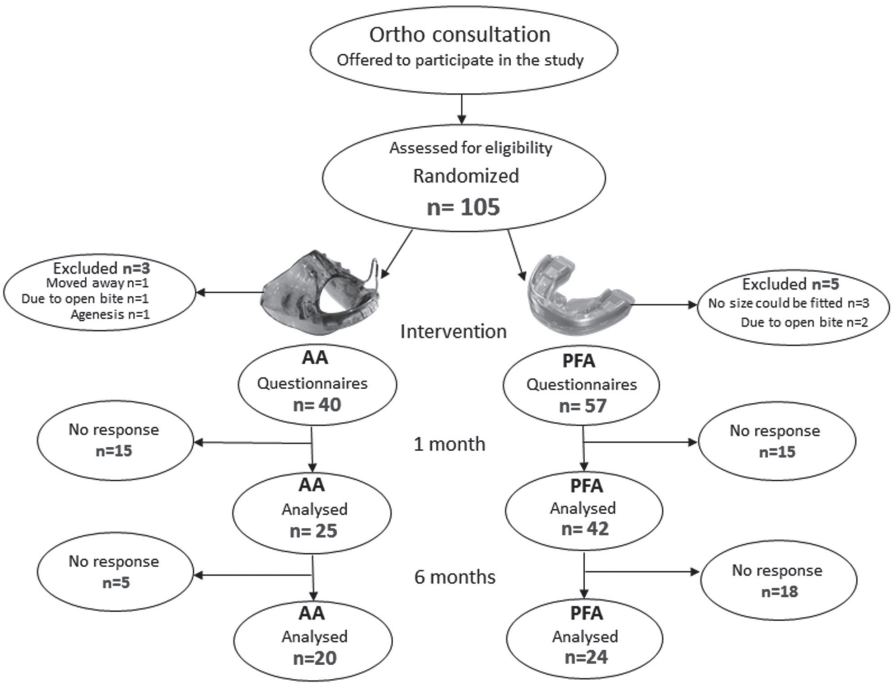

Figure 13. Flow chart of the participants in the study and questionnaire responses one and six months after the start of treatment. AA, Andresen activator; PFA, prefabricated functional appliance.

Discomfort, expectations and experiences

The most common discomfort reported was the appliance falling out during sleep, followed by difficulties in remembering to use it. The only statistical difference found between the AA and PFA groups was for pain, experienced more in the AA group after one month of treatment.

Expectations of improved oral health, and enhanced dental aesthetics from the treatment, were high. Patient dissatisfaction with teeth focused mainly on appearance (24%), and very little on function (1%). The dentist seemed to have the largest impact on the decision to start treatment, and teasing due to teeth appearance occurred in 13 per cent of cases.

Patients appeared to be well informed about recommended appliance usage time and care, but least informed on what to do in case of appliance breakage, or the appliance falling out during sleep.

Perceptions of the treatment – Paper III

Participant flow

A total of 21 Swedish-speaking adolescents agreed to take part in the interviews. Eleven subjects (six girls, five boys) from the success group (S), and 10 subjects (six girls, four boys) from the failure group (F), agreed to share their experiences of the treatment with a functional removable appliance. The mean age of the participants was 13.2 years (range 11– 15, SD 1.25) at the interview occasion.

Outcomes

The analysis of the 21 individual interviews emerged in five main categories with 12 subcategories that describe the adolescents' various conceptions of the treatment.

The first category "Initial individual approach" concerned the individual´s perspective of participating in the decision to start treatment.

> *"I really wanted to see if it worked, whether there would be an improvement, or if it was a waste of time." (Girl, 15 years)*

The second category "Feeling of individual discomfort" dealt with individual discomfort due to the treatment.

> *"I got a bit tired. Couldn't really hold it, or to bite down on it. And at night when I was sleeping, it would just fall out, or, well I wasn't biting that hard on it then." (Boy, 13 years)*

In addition, statements indicated how embarrassing it was having an appliance, and how this could be a reason to be bullied.

The third category "Developing individual strategies" described how different strategies were developed by participants to manage remembering the appliance, and seeing or measuring improvement.

> *"It helped loads. I even noticed how well it worked. I was pleased with it. And because of that I was motivated to continue using it. I had a little thing with my thumb, which I used to measure it with, and it always improved, or the space became less. It worked really well. " (Boy, 15 years)*

The fourth category "Meeting the dentist" contained conceptions associated with experiences from the visits at the dentist, and interaction between the adolescents and dentist.

> *"As I said, I would have preferred to have fixed braces. He had already decided that it (myobrace) was the best choice. In the beginning, I tried to use it as much as possible. After a while though, I got tired of it" (Girl, 13 years)*

The fifth category, "Gaining external support", covered the participants' conceptions related to external influences and support.

> *"Because it was hard I couldn't be bothered to wear it, but mum forced me " (Boy, 13 years)*

The statements in this category also revealed that Friends' attention could be both positive and negative factor.

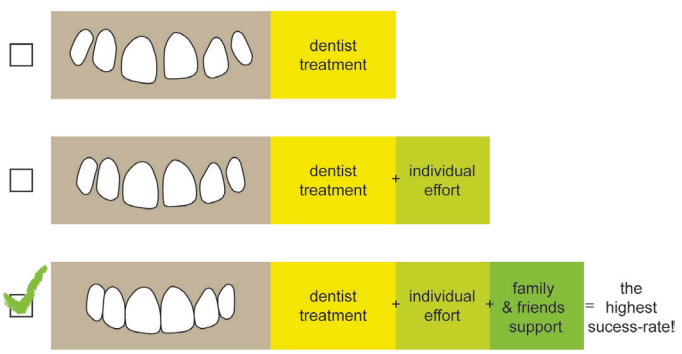

Figure 14. Overview of different factors contributing to successful treatment experienced by adolescents.

Treatment costs - Paper IV

Participant flow

Figure 15 illustrates the flow of participants through the study.

Number of appointments

The number of appointments was significantly higher in the AA group, both for the ITT and unsuccessful cases. However, the average number of appointments for patients with successful treatment outcomes showed no significant differences between the two groups, AA and PFA, while the number of emergency visits was significantly higher for the AA than for the PFA group.

Costs

Significant differences in direct, indirect, and societal costs were found between the AA and PFA for all subgroups, i.e. ITT, successful and unsuccessful outcomes, in that costs were higher in the AA than in the PFA groups.

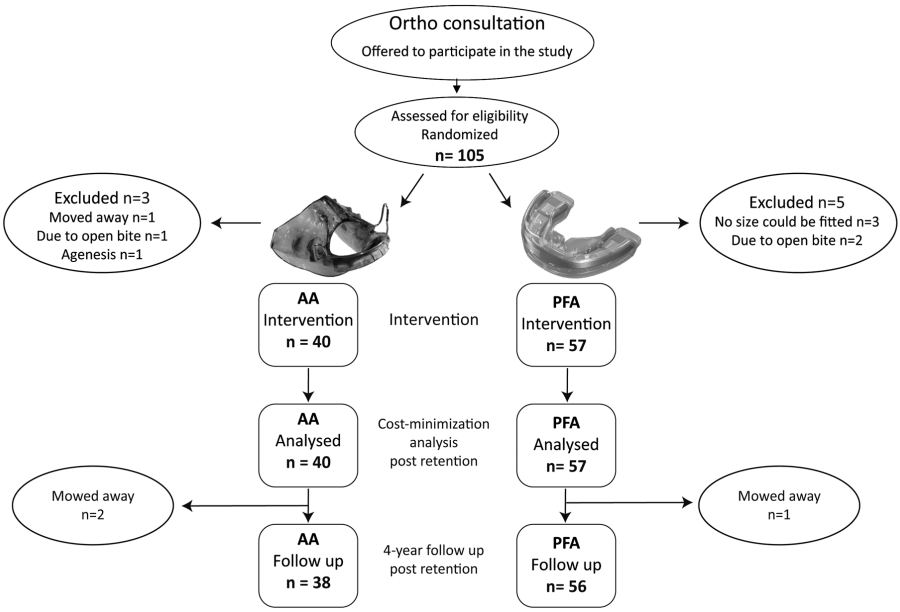

Figure 15. Flow chart of the participants in the study (Paper IV). AA, Andresen activator; PFA, prefabricated functional appliance.

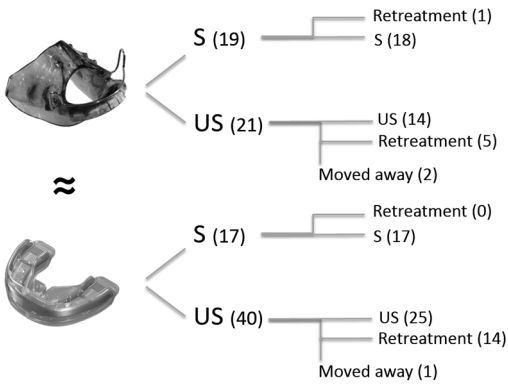

Figure 16. Flow chart of the 4-year post-retention period. AA, Andresen activator; PFA, prefabricated functional appliance. US (unsuccessful group) S (successful group).

Retreatment

In the successful group, retreatment of large overjet with a removable functional appliance was performed on one patient in the AA group, and none in the PFA group (Figure 16). Among the unsuccessful cases in the AA and PFA group, 26 per cent and 36 per cent of the patients underwent retreatment of the large overjet, respectively.

The most common retreatment was performed with headgear activators on an average of 1.5 years post retention (Table 6). No long-term follow up monitoring was possible in 3 cases (Figure 16).

Table 6. Number (n) of retreatment of large overjet with removable functional appliance used mean 1.5 years (0.5-3 years) post intervention.

Retreatment with removable appliance	n=21
Appliance type:	
- Headgear activator (HA)	n=14
- Removable plate (RP)	n= 3
- Combination (RP+HA)	n= 4

DISCUSSION

The main object of study for this thesis was the treatment of large overjet in preadolescents. The study question was to determine whether a Prefabricated Functional Appliance (PFA) could be used to treat patients with large overjet as effectively as a well-known appliance, such as the Andresen Activator (AA). One advantage of the PFA is that it eliminates the unpleasantness of taking dental impressions.

Two approaches were used, one aiming to evaluate the effectiveness and cost of the treatment, and the other to better understand patients' experiences of the treatment.

The main findings were that treatment with the Andresen Activator (AA) and the Prefabricated Functional Appliance (PFA) were equally effective in the correction of large overjet. Both appliances showed, however, a low success rate (37 per cent), with no differences in the frequency of retreatments at the 4-year follow-up. The most common discomfort, reported by patients, was the appliance falling out during sleep, followed by forgetting to use it. Teasing, because of tooth appearance, occurred in 13 per cent of the cases. From a patient perspective both appliances were highly accepted, and could be recommended. The adolescents' experiences of using a removable functional appliance varied considerably, depending on their approaches, feelings, and strategies, the dentist's role, and external support. The patients developed strategies for measuring improvement in overjet. However, total costs were significantly lower for the PFA compared to the AA, and the number of visits was lower in the PFA group. To summarize, the PFA, when compared to the AA, is the preferred approach in the reduction of large overjet in mixed dentition. Furthermore, dental impressions are often considered unpleasant, and treatment with the PFA eliminates the need for taking dental impressions. This could be a considerable advantage when treating young patients with large overjet to reduce the risk for maxillary incisor trauma (Thiruvenkatachari, Harrison et al. 2015), and consequently prevent teasing or bullying.

Limitations and strengths

One of the strengths of this thesis is its use of three research approaches: an RCT (Paper I), a qualitative study using interviews and questionnaires (Papers II and III), and a cost evaluation (Paper IV).

No cephalometric records were taken, as only patient-centred clinical outcomes were used as an indicator for treatment success. Growth modification with removable functional appliances has been investigated in several RCTs, and systematic reviews show that correction of the molar and incisal relationship is mainly a result of dentoalveolar changes (Thiruvenkatachari, Harrison et al. 2013, Koretsi, Zymperdikas et al. 2015, Pacha, Fleming et al. 2015). The criteria of reduction of overjet to as low as 3 mm affected the success rate in this study compared to other studies with larger overjet values considered successful (Rizell, Svensson et al. 2006, Casutt, Pancherz et al. 2007). However, clinical measurements where blinding is not possible, could entail a risk for bias.

The sample size analysis was performed before the study began, and was considered appropriate for our specific research objectives, i.e. overjet correction. Additionally, as in all studies with compliance-dependent factors, the practical sample size falls below the actual size. A high risk of dropouts and non-compliant patients was anticipated, based on the results of previous studies. We therefore aimed to include 240 patients, compared with the 76 patients required according to the sample size analysis. However, it took long to recruit patients, so we decided to stop when 105 participants were included in the study. This was the cause of the uneven randomization. An alternative could have been a different randomization design, e.g. stratification.

By choosing an RCT design, we aimed for the highest level of evidence. The random distribution of subjects reduces bias and confounding factors by ensuring that both known and unknown factors of outcome are equally distributed among subjects. Generally, an RCT can be considered superior when ITT is used, in which each patient record is evaluated, regardless of treatment outcome. As a consequence, possible biases deriving from the age range, or differences in psychological development and perceptive mechanisms, may be minimized. The randomization process also reduces the risk of error due to factors such as selection bias, the clinician's favored treatment method, and individual differences in skills of the general dental practitioner. However, overall clinical skills, or lack of experience, could still be a confounding factor in studies with small samples (Bergstrom and Halling 1996).

One could argue that a weakness of this study was the involvement of many operators, and therefore all GPs, as well as the six orthodontists, were calibrated in the measuring and registration procedures. Differences in clinical experience among operators could, however, influence the results as reported earlier (Sepanian, Paulsson-Björnsson et al. 2014). On the other hand

the involvement of several operators in carrying out treatment could also be considered strength. Treatment outcomes from a larger number of operators makes the patient-related treatment outcomes more general than if only one or two clinicians performed the treatment in a university environment.

Furthermore, one survey instrument (a perception questionnaire) may have posed potential problems related to the low response rate, since the questionnaires were distributed anonymously, without registration of the patient, clinic, or dentist. This procedure, however, also made it impossible to follow changes in discomfort over time for each participant, or analyse failures to complete questionnaires. If all questionnaires had been completed at the clinic, the response rate could have been higher, but lack of time for both patients and dentists may have resulted in hasty decisions and responses.

Variation in the participants' ages may have influenced outcome. Still, the aim was, despite age differences, to investigate a patient's own experience, although they could receive some help from their parents concerning question interpretation. Age variation is normal, since removable functional appliances are generally used for both early and late mixed dentation, which will include individual variation from approximately 7 to 14 years of age, depending on somatic and dental development (Idris, Hajeer et al. 2012, Hedlund and Feldmann 2016).

Open questions were added to the questionnaire to strengthen the study, wherein participants could express treatment experiences more freely. Unfortunately, there was no question in the survey as to whether the patient had taken analgesics due to initial pain caused by the appliance, nor history of previously experienced pain.

The advantage of using a phenomenographic approach in the interviews was its ability to explore variations of the phenomena, adolescents' experiences of the treatment with a removable functional appliance. A pilot study, including both individual and focus group interviews, was carried out to test the interview outline and questions. This gave the study greater impact, ensuring proper design for exploring the phenomena by individual interviews. Additionally, to make sure of reliability, an examination of trustworthiness was performed.

Another weakness of this study was the interviewer's (EC) pre-knowledge of the appliances and treatment, but the adolescents did not know her in advance.

Furthermore, participants completing the indirect cost questionnaire (Table 2) were not parents to the RCT subjects, but were matched by clinic and orthodontic treatment visits.

It is important to bear in mind that costs are dependent on local factors, thus these findings should not be directly extrapolated to other settings. For cost evaluation we did not use wage estimates, but a questionnaire, to obtain more exact and individualized data regarding salaries, travel costs, and parental leave of absence.

Subjects

Participants in the studies for this thesis were consecutively recruited from 12 general dental practices in Gothenburg, Sweden, and represent patients from a wide urban area. Thus, the selection can be considered representative of preadolescents with large overjet. Patients with crossbite, severe crowding, agenesis, other malocclusions or syndromes, were excluded, since the primary aim of this thesis was to evaluate the correction of large overjet. All participants were diagnosed twice, whereby both the general practitioner and the consulting orthodontist examined the patients prior to randomization.

One could argue that the close observation of patients in a trial provides positive outcomes that may not be applicable to everyday clinical conditions, and that the data should not, therefore, be extrapolated to the general population. The patients taking part in the present RCT were treated by general dental practitioners in local clinics under the supervision of a consultant orthodontist, simulating normal conditions for treatment of large overjet in the Swedish Dental Health Care system. The outcomes can, therefore, be expected in the general population aged 6–14 years, if the above-mentioned inclusion criteria are met.

In contrast to the Swedish National Bureau of Statistics' register, our participants came from a city, meaning our results regarding cost minimization can only be used for urban areas and large cities in Sweden.

Treatment effects

Early correction of Class II malocclusions with removable appliances is, in Sweden, often undertaken by a GP after consultation with an orthodontist (Petrén, Bjerklin et al. 2014). Thus, we chose to evaluate the efficacy of this treatment in a representative urban population, performed by dentists in their regular practices at the Public Dental Health Services. The activator developed by Andresen (AA) is a commonly used functional appliance, therefore we chose this well-known appliance (Follin, Kahnberg et al. 1993, Petrén, Bjerklin et al. 2014) to compare it with the rarer PFA.

There is considerable variation regarding treatment outcome of functional appliances. Functional appliances have been extensively investigated with regard to skeletal and dentoalveolar changes in response to treatment. Much clinical research has focused on the effect of treatment on clinical growth patterns (Pancherz 1976, Pancherz 1979, Ruf and Pancherz 1996, Janson, Pereira et al. 1997, Cozza, De Toffol et al. 2004, Keski-Nisula, Keski-Nisula et al. 2008), and have been investigated in several randomized trials (Keeling, Wheeler et al. 1998, Tulloch, Phillips et al. 1998, O'Brien, Wright et al. 2003). Although the treatment results are often satisfactory, skeletal treatment changes are, on average, not very large, and quite unpredictable, with large inter-individual variation (Carels and van der Linden 1987, Bishara and Ziaja 1989, Tulloch, Medland et al. 1990, Woodside 1987, Das and Reddy 2010, Thiruvenkatachari, Harrison et al. 2013), concluding that early treatment provides correction of the incisal relationship, mainly due to dentoalveolar changes (Thiruvenkatachari, Harrison et al. 2013, Koretsi, Zymperdikas et al. 2015, Pacha, Fleming et al. 2015).

The large variation in treatment changes among patients is often attributed to compliance issues, but evidence of patients' perceptions of treatment is not very well known (Tsichlaki and O'Brien 2014).

Our study showed no significant differences in results during the total observation period for the AA and PFA groups, either for overjet, overbite reduction, or correction of the sagittal molar relationship, correction, and improvement of lip seal. This is in agreement with a study that reported similar occlusal changes when comparing patients wearing the Fränkel appliance and the eruption guidance appliance (Janson, de Souza et al. 2004).

Only 40 per cent of the patients with a full Class II relationship were corrected to Class I during treatment, and in the follow-up period relapse occurred in 10 per cent. Furthermore, self-correction in the unsuccessful group was observed. This could probably be explained by the loss of the mandibular deciduous second molars. Bishara (1988) reported a spontaneous mesial drift of the lower molars on exfoliation of the second primary molars in approximately 60 per cent of untreated, flush terminal occlusion subjects, depending on the interdigitation of the teeth. Such a spontaneous mesial drift of the molars could result in an improvement of the occlusal relationship, even without orthodontic intervention (Bishara and Jakobsen 1988). More favorable treatment changes than in the present study were seen in sagittal dental relationships in a Norwegian and Finish study of the eruption guidance appliance. An explanation of this difference might be that these studies comprised much younger patients, and no long-term follow-up (Keski-Nisula,

Hernesniemi et al. 2008, Keski-Nisula, Keski-Nisula et al. 2008, Myrlund, Dubland et al. 2015). There are even RCT studies (Ghafari, Shofer et al. 1998, Wheeler, McGorray et al. 2002) showing that retention does not necessarily retain sagittal molar correction.

Both increased overjet and inadequate lip seal are considered significant risk factors for dental trauma on the maxillary incisors (Burden 1995). Our results reveal that lip seal improvement was significant, and with no difference between the PFA and AA groups. Even the unsuccessful group improved significantly (38 per cent) in lip seal during treatment. This could possibly be due to awareness of the lip seal problem during initial training with the appliance. Soft tissue changes following functional appliance treatment have been studied mainly in cephalometric studies, and according to available evidence regarding soft tissue changes, produced by the Activator and the Bionator, were statistically significant, but of questionable clinical significance (Flores-Mir and Major 2006). However, the position of the lips while taking cephalometric radiographs varies, since the normal procedure is in centric occlusion, and not in a resting position, which is required if natural lip seal is to be evaluated.

In individual studies of Class II treatment with functional appliances, one can often observe small mean treatment changes, and large standard deviations. One factor that could partially explain inter-individual differences in response to functional appliance treatment may be the masticatory musculature and its functional capacity. Antero-posterior intermaxillary forces exerted by functional appliances during treatment display a large variation, and can vary in magnitude between 0.25 and 5 Newtons, and in direction (Noro, Tanne et al. 1994, Katsavrias and Halazonetis 1999). This variation is present both between patients, and within the same patient, during the treatment period. In parallel, it is known that masticatory muscle capacity varies significantly between growing individuals, as measured both by bite force (Proffit and Fields 1983, Kiliaridis, Kjellberg et al. 1993, Braun, Bantleon et al. 1995, Ingervall and Minder 1997), and masseter muscle thickness (Raadsheer, Kiliaridis et al. 1996). Treatment of a dental Class II relationship with functional appliances leads to a decrease in the masticatory muscle's activity, possibly because of alterations in muscular function (Kiliaridis, Mills et al. 2010). The initial condition of the masticatory muscles may partly determine treatment outcomes. Children with thinner pre-treatment masseter muscles, or a weaker bite, seem to show larger dental movements (Antonarakis and Kiliaridis 2015).

Participants with a successful treatment outcome had significantly longer treatment compared with the unsuccessful group. No significant difference was found between the AA and PFA groups (Table 3). This is in contrast to other studies where duration of treatment tended to be longer for the less successful group (Cohen 1981, Janson, de Souza et al. 2004). One explanation could be that we used standardized protocols in this study, asking operators to discontinue treatment if no change of overjet was recorded within the past 6 months.

When trying to explain the low success rate found in our study, we realized similarities with another multicenter RCT carried out in the UK (O'Brien, Wright et al. 2003), where an explanation of the low success rate was that the study was carried out in a "real world" setting, i.e. the same setting as in the present study, rather than in a dental school with 1 or 2 operators. Furthermore, as all treatments in the present study were provided cost-free, it could be speculated that paying a fee may have influenced cooperation in a positive way, as seen in a recently published study (Schafer, Ludwig et al. 2015).

Patient experience of the treatment

The patients, described as subjects and participants in this thesis, were invited to share their experiences of the treatment in a questionnaire and individual interviews. Overall, oral pain was common, while social discomfort was considered only a minor problem (Paper II). Idris et al., (2012) reported similar results regarding pain between a modified Andresen activator and a prefabricated appliance. For social discomfort, on the other hand, Idris et al., (2012) found that the Andresen activator was more widely accepted than the Trainer appliance (another kind of PFA), which contradicts our findings wherein both appliances were equally accepted (Idris, Hajeer et al. 2012).

Discomfort and unpleasant effects from pressure and muscle tension in the muscles and mucosa caused by functional appliances (Sergl and Zentner 1998) could also be factors explaining low compliance for removable functional appliances (Rizell, Svensson et al. 2006, Sepanian, Paulsson-Björnsson et al. 2014, Hedlund and Feldmann 2016). Furthermore, it has been reported that the Twin-block appliance had a more negative effect on speech, sleep patterns, and schoolwork, compared with a fixed functional, Herbst appliance (O'Brien, Wright et al. 2003), thus, Activators, and other one-piece and loose fitting appliances, may also be expected to lead to similar impairment as Twin-blocks. Nevertheless, a previous study concluded that

most complaints, including speech and swallowing difficulties, discomfort, and lack of confidence, subside significantly, but gradually after the first week of use (Sergl, Klages et al. 2000).

The experience of our pilot interviews was that adolescents seemed shy and uncomfortable talking about removable appliances in groups. This was also mentioned during the individual interviews. This is in line with earlier studies, indicating that patients with a failed treatment felt more embarrassed with their families than those who completed the functional phase (O'Brien, Wright et al. 2003). The lack of studies assessing patient-centred outcomes highlights the need for such studies to gain a better understanding of the influence of these factors on patient adherence (Tsichlaki and O'Brien 2014).

According to Crawford (1974) most adolescent patients base their desire for orthodontic treatment on aesthetics rather than function (Crawford 1974), and there were high expectations of better dental appearance (Twigge, Roberts et al. 2016). This is in agreement with our results where patient dissatisfaction seemed to concern appearance (24%) rather than function (1%). Being bullied has also been suggested to be significantly associated with Class II Division 1 malocclusion, and increased overjet and overbite (Seehra, Fleming et al. 2011). Individuals with prominent incisors were commonly associated with nicknames such as "Goofy, Bugs Bunny, and Sticky out teeth" (Shaw, Meek et al. 1980, Al-Bitar, Al-Omari et al. 2013). This is in accordance with our study, where teasing due to teeth appearance occurred in 13 per cent of cases, with the most common phrase for harassment being "Rabbit teeth" (89%).

The significant disadvantage of removable functional appliances is the onus of patient compliance, with failure to complete treatment reported at 34 per cent (O'Brien, Wright et al. 2003), and 63 per cent in our study. Furthermore, getting patients involved in treatment decisions, and increasing awareness of their responsibility for treatment success, are important for maintaining high levels of adherence (Mollov, Lindauer et al. 2010). Nevertheless, willingness to wear a removable appliance increased markedly when orthodontic objectives included offering patients the prospect of improvement in their facial appearance (Schott and Goz 2010).

It may have been better to use more objective measures of cooperation such as timing devices or logs of hours of appliance wear, since research shows (Schott and Goz 2010, Schafer, Ludwig et al. 2015) that to improve compliance, it must be measured. This was also evident in this study, from the patient's statements (Paper III), whereby some participants developed their own measurement strategies to assess improvement. Participants also proposed that individual treatment information and recommendations were sought after. A recently

published interview study of treatment expectations of adolescents confirms this by promoting an individual approach to orthodontic patient management, and the importance of good communication (Twigge, Roberts et al. 2016). This may later lead to individualized prescriptions for wear time, using microelectronic wear-time documentation. Individual prescriptions based on wear-time documentation could result in a shared patient - doctor decision-making processes to achieve more effective and successful treatments (Schott and Ludwig 2014, Schott, Meyer-Gutknecht et al. 2016).

An interview study by Trulsson et al. (2004) examined age differences, and illustrated the importance of more parental involvement for younger children's compliance. They suggested that if treatment compliance cannot be ensured through parents' enthusiastic involvement, it would seem better to delay treatment (Trulsson, Linlav et al. 2004). This was also found earlier (Albino, Lawrence et al. 1991), and is in agreement with our findings, and the adolescents' experiences of using removable functional appliances appear highly varied, comprising individual approaches, dentist roles, and external support. The relationship between orthodontist and patient seems to play a vital role in patient adherence (Allan and Hodgson 1968, Trulsson, Linlav et al. 2004, Schafer, Ludwig et al. 2015).

Cost evaluation

The cost of early treatment can be analysed in several ways. The choice of method depends on the available data and the perspective to be studied. The present cost analysis was based on the RCT outcome (Paper I).

A recent Cochrane systematic review reported no statistically significant differences in overjet reduction between one-phase (fixed appliance during adolescents) and two-phase treatment (functional appliance at a young age plus later treatment with a fixed appliance). However, the incidence of new incisal trauma showed statistically significant results in favour of a functional appliance in a two-phase treatment compared with a one-phase treatment during adolescence (Thiruvenkatachari, Harrison et al. 2013). Early treatment of large overjet is thus only supported as cost beneficial for trauma prevention.

General practitioners treated the patients in the present study. As these practices are often located closer to the patients' homes than an orthodontic specialist clinic, the indirect costs for patients and parents in this case could be lower, and thereby compensate for more higher direct costs if a specialist with a higher salary would have performed the treatment.

Emergency appointments have been shown to be less frequent in a PFA

group compared to a Twin-block and an Activator-Headgear appliance group (Nilsson, Shu et al. 2016). This was in line with the results of the successful group in our study, although they only presented a 9-month treatment period in a specialist clinic, and only reported results for successful cases (Nilsson, Shu et al. 2016).

A recent retrospective study evaluated treatment costs of a modified headgear activator (Hedlund and Feldmann 2016). They reported longer treatment time, longer chair time, and more appointments compared to the results for the AA group of the present study. This might be due to the retrospective design, not following standardized protocol with a defined cut-off point for unsuccessful treatment, retention time, and different appliance design. Indirect costs were, however, lower than those we found in our questionnaire analysis (Table 2) with individual data regarding salaries and parental absence from work, probably because they used estimates of wages, with no travel expenses included.

Cost-minimization data will gradually become an important part of health care planning, particularly if the state is a major stakeholder. Thus, the characteristics of PFA might be of economic benefit to our dental health care system.

Clinical significance of the findings

A removable functional appliance may be a difficult appliance to wear. The clinical results of the present RTC show high failure rates for both AA and PFA cases. The reasons for discontinuing treatment were mainly due to problems with compliance, lack of motivation, lack of parental support, and not being listened to before the start of treatment, showing the importance of evaluating these parameters before initiating treatment.

Our findings also revealed that teasing due to teeth appearance occurred in 13 per cent of cases with the most common phrase for harassment being "Rabbit teeth" (89%).

The total costs for treatment, with PFA or AA, of large overjet were estimated between 950-1550 €. Since about 30 per cent of the unsuccessful cases received retreatment for large overjet this makes the total cost of treatment even higher. This reflects normal conditions for treatment of large overjet in the Swedish Dental Health Care system. Therefore, it would be useful to be able to identify the "at risk" patient, i.e. the one likely to discontinue treatment irrespective of appliance, since unsuccessful treatments are very expensive with no benefits either to patients or society.

Previous studies have shown that the general practitioner often awakens interest for orthodontic treatment (Brattstrom, Ingelsson et al. 1991, Trulsson, Linlav et al. 2004, The Swedish Council on Technology Assessment in Health Care 2005). This was confirmed in our findings where the general practitioner also seemed to have the largest impact (51%) on the decision to start orthodontic treatment, followed by mothers and the patients themselves (21%).

Furthermore, according to evidence, early treatment of large overjet is only supported as cost beneficial for trauma prevention. An active involvement of the patient, motivated parents with understanding, and encouraging clinicians were suggested to increase the chances of successful treatment. PFA is the preferred approach for reduction of large overjet in mixed dentition, since it minimizes costs, and the clinical outcomes between PFA and AA are equal. These aspects should be considered during selection of patients and treatment planning.

CONCLUSION

PAPER I

PFAs are as effective as AAs in correcting overjet, overbite, sagittal molar relation, and lip seal. The success rate of treatment with both appliances is, however, low.

PAPER II

No difference could be seen between groups for the experience of functional or social discomfort after 6 months of appliance use. The most common discomfort, equally described in both groups, was the appliance falling out during sleep followed by difficulties remembering to insert it at bedtime.

Sufficient time should be allowed to explain the severity of the treatment, and provide advice if the appliance falls out during sleep, using treatment need as motivation.

The dentist seemed to have the greatest impact on the decision to start orthodontic treatment, followed by mothers and the patients themselves.

The contribution of orthodontic treatment in victimization should not be underestimated, whereby teasing due to teeth appearance occurred in 13 per cent of the cases.

PAPER III

The results revealed the importance of internal motivation and external support during treatment. Participants developed their own strategies of measurement to see improvement. An active involvement of the adolescents in treatment seems to be necessary, supported by the dentist in coming appointments, using overjet measurement as a tool for motivation. Furthermore, efforts should be made by clinicians to listen and understand adolescents' needs and requirement before treatment start.

PAPER IV

PFA is the preferred approach for reduction of large overjet in mixed dentition, since it minimizes costs, and shows equally successful clinical outcomes as the AA.

Both appliances (AA and PFA) showed a low success rate for overjet correction, and no difference in frequency of retreatments, but the PFA eliminates the need for taking impressions, which can be advantageous for both patients and clinicians.

FUTURE PERSPECTIVES

More attention should be paid to the daily impact of malocclusion. Clinical evaluation should be combined with validated instruments that explore patient demand for treatment. Dentist should listen to their patients and actively involve them in treatment (including family and friends for support) as the family plays an important role for a successful outcome.

We will continue to explore experiences of treatment with removable functional appliances and family impact by interviewing the parents of the participants.

More well designed research is needed in the future to increase our knowledge of patients' experiences of removable functional appliances: e.g., on the influence of appliance type on patient perceptions. The influence of the operator's skills and professional status on the patient's perception of treatment also deserves further investigation.

The objective measurement of wearing times has the potential to cause a paradigm shift in orthodontics. Instead of prescribing the patient's wearing times based on experience, as has been done for decades, a wearing-time regimen can now be customized on the basis of the wearing-time graph, and on how the therapy is progressing, while keeping in mind the patient's needs and abilities.

Furthermore, costs of interceptive treatment should be related to outcome to ensure the best value for money. Therefore, future studies should include an economic evaluation of the entire intervention, hence describing the true input and outcome costs.

ACKNOWLEDGEMENTS

I would just like to add a few, but very important, closing words to this thesis by expressing my heartfelt gratitude to the countless people, who in their own ways have helped, supported, and encouraged me, throughout this journey, and who made this thesis possible.

My thanks to:

All the children and parents for their participation in the clinical studies: without them this work would not have been possible.

Associate Professor Ken Hansen, my great mentor and main supervisor, whose encouragement and persistent support made this thesis a reality. Thank you for being a key source of inspiration, sharing your brilliant scientific knowledge with thought-provoking discussions. I sincerely appreciate all your support and belief in me. Thank you for your generosity, patience, and time, always answering my questions, calls, and emails, whenever or wherever you were!

Associate Professor Heidrun Kjellberg, my amazing mentor and co-supervisor, whose endless enthusiasm and extensive knowledge also made this thesis possible. Thank you for your valuable scientific guidance, stimulating discussions, and for always being there for me. You have been a major source of inspiration.

Professor Bengt Mohlin, my co-supervisor, for valuable support and stimulating discussions, particularly in the beginning of the study. Thank you for your supervision and enthusiasm.

Professor Margret Lepp, my co-supervisor, who introduced me to the qualitative world of research. Thank you for sharing your invaluable knowledge, enthusiasm, and guidance in qualitative methods.

Professor Max Petzold, my co-author in Paper IV and excellent statistician. Thank you for your invaluable input, guidance, and for always quickly answering my questions and safely guiding me through the minefield of statistics.

Senior Professor Björn Lindgren, for contributing to the design of Paper IV.

Odont. Dr Thomas Örtendahl, my dear mentor and colleague, for inspiration and helping the start of my career.

Odont. Dr Eva-Karin Bergström, colleague and friend, for so generously sharing your knowledge of qualitative research.

Amin Karzan and Rashed Rouhollah, dental students, for helping with the registration and processing of data in Paper II.

Charlotte Kjellberg and Caroline Hermansson for their help in transcribing the interviews in Paper III.

Elona Baho and Pegah Mazloum, dental students, for helping with the registration and processing of data in Paper IV.

All participating dentists from 12 public general dental practices in Gothenburg, Region Västra Götaland for their fantastic teamwork.

Tic DP Nova for their excellent collaboration.

My dear colleagues and friends at Dental Health Clinic, Varberg for your encouragement and support during this work.

All the colleagues, co-workers and friends at The Orthodontic Clinic in Gothenburg, Sweden, for recruiting participants and generously providing me with their great support. Thank you for believing in me.

My dear friend Eva Ryberg, great artist, for your support, amazing illustrations, the cover and Paper III image, and for our long lasting friendship.

All my friends, for being there for me. Thank you!

The best brother ever, Demir, who has always been there for me, with great love. I express my highest gratitude for your support and help in organizing my technical supplies. "*Stoko, volim te!* "

I would like to especially thank *my parents Mesuda and Hajrudin-Dino*, for your unlimited love and guidance throughout my life. Thank you from the bottom of my heart for your endless support and encouragement. You are my life´s greatest winning ticket, with you in my life I can never fail."*Majkic & Tatkic, vi ste najbolji roditelji na svijetu. Volim vas puno!*"

Last but certainly not least,

My lovely "Bobo", I don´t know how to thank you! I couldn't have done this without your patience, constant support and loving care. Thank you for pushing me out into the real world and making my life such a happy one. "*V.T.M.*"

Grants

We would like to thank the Council for Research and Development in the Västra Götaland Region, Gothenburg Dental Society and the Swedish Dental Society for supporting this study.

REFERENCES

Aelbers, C. M. and L. R. Dermaut (1996). "Orthopedics in orthodontics: Part I, Fiction or reality--a review of the literature." Am J Orthod Dentofacial Orthop 110(5): 513-519.

Aguiar-Ibanez, R., J. Nixon, J. Glanville, D. Craig, S. Rice, J. Christie and M. F. Drummond (2005). "Economic evaluation databases as an aid to healthcare decision makers and researchers." Expert Rev Pharmacoecon Outcomes Res 5(6): 721-732.

Ahlgren, J. (1972). "A longitudinal clinical and cephalometric study of 50 malocclusion cases treated with activator appliances." Trans Eur Orthod Soc: 285-293.

Ahlgren, J. (1978). "Early and late electromyographic response to treatment with activators." Am J Orthod 74(1): 88-93.

Ahlgren, J. (1983). "[Oral screen activator. A modified Andresen activator]." Tandlakartidningen 75(6): 300-301.

Al-Bitar, Z. B., I. K. Al-Omari, H. N. Sonbol, H. T. Al-Ahmad and S. J. Cunningham (2013). "Bullying among Jordanian schoolchildren, its effects on school performance, and the contribution of general physical and dentofacial features." Am J Orthod Dentofacial Orthop 144(6): 872-878.

Albino, J. E., S. D. Lawrence, C. E. Lopes, L. B. Nash and L. A. Tedesco (1991). "Cooperation of adolescents in orthodontic treatment." J Behav Med 14(1): 53-70.

Allan, T. K. and E. W. Hodgson (1968). "The use of personality measurements as a determinant of patient cooperation in an orthodontic practice." Am J Orthod 54(6): 433-440.

Andresen, V. (1914). Tandretning. Köpenhamn, H. Hagerup's forlag.

Andresen, V. (1940). "Über das Norwegische System der Funktions-Kieferorthopädie." Schweizerische Monatsschrift für Zahnheilkunde 50(3).

Andresen, V., K. Häupl and L. Petrik (1953). Funktions-Kieferorthopädie Munchen, Barth.

Antonarakis, G. S. and S. Kiliaridis (2015). "Predictive value of masseter muscle thickness and bite force on Class II functional appliance treatment: a prospective controlled study." Eur J Orthod.

Antonarakis, G. S., H. Kjellberg and S. Kiliaridis (2013). "Bite force and its association with stability following Class II/1 functional appliance treatment." Eur J Orthod 35(4): 434-441.

Araujo, A. M., P. H. Buschang and A. C. Melo (2004). "Adaptive condylar growth and mandibular remodelling changes with bionator therapy--an implant study." Eur J Orthod 26(5): 515-522.

Association, W. M. (2013). "World Medical Association Declaration of

Helsinki: ethical principles for medical research involving human subjects." Jama 310(20): 2191-2194.

Atkins, D., D. Best, P. A. Briss, M. Eccles, Y. Falck-Ytter, S. Flottorp, G. H. Guyatt, R. T. Harbour, M. C. Haugh, D. Henry, S. Hill, R. Jaeschke, G. Leng, A. Liberati, N. Magrini, J. Mason, P. Middleton, J. Mrukowicz, D. O'Connell, A. D. Oxman, B. Phillips, H. J. Schunemann, T. Edejer, H. Varonen, G. E. Vist, J. W. Williams, Jr. and S. Zaza (2004). "Grading quality of evidence and strength of recommendations." Bmj 328(7454): 1490.

Backstrom, A. (1985). "[Orthodontic consultation in public health dentistry]." Tandlakartidningen 77(5): 219-222.

Bartsch, A., E. Witt, G. Sahm and S. Schneider (1993). "Correlates of objective patient compliance with removable appliance wear." Am J Orthod Dentofacial Orthop 104(4): 378-386.

Bauss, O., J. Rohling and R. Schwestka-Polly (2004). "Prevalence of traumatic injuries to the permanent incisors in candidates for orthodontic treatment." Dent Traumatol 20(2): 61-66.

Bergersen, E. O. (1984). "The eruption guidance myofunctional appliances: how it works, how to use it." Funct Orthod 1(3): 28-29, 31-25.

Bergersen, E. O. (1985). "The eruption guidance myofunctional appliance: case selection, timing, motivation, indications and contraindications in its use." Funct Orthod 2(1): 17-21, 24-15, 28-33.

Bergstrom, K. and A. Halling (1996). "Orthodontic care provided by general practitioners and specialists in three Swedish counties with different orthodontic specialist resources." Swed Dent J 20(1-2): 35-50.

Birkebaek, L., B. Melsen and S. Terp (1984). "A laminagraphic study of the alterations in the temporo-mandibular joint following activator treatment." Eur J Orthod 6(4): 257-266.

Bishara, S. E., B. J. Hoppens, J. R. Jakobsen and F. J. Kohout (1988). "Changes in the molar relationship between the deciduous and permanent dentitions: a longitudinal study." Am J Orthod Dentofacial Orthop 93(1): 19-28.

Bishara, S. E. and R. R. Ziaja (1989). "Functional appliances: a review." Am J Orthod Dentofacial Orthop 95(3): 250-258.

Bondemark, L., A. K. Holm, K. Hansen, S. Axelsson, B. Mohlin, V. Brattstrom, G. Paulin and T. Pietila (2007). "Long-term stability of orthodontic treatment and patient satisfaction. A systematic review." Angle Orthod 77(1): 181-191.

Bondevik, O. (1991). "How effective is the combined activator-headgear treatment?" Eur J Orthod 13(6): 482-485.

Bondevik, O. (1998). "Changes in occlusion between 23 and 34 years." Angle Orthod 68(1): 75-80.

Brattstrom, V., M. Ingelsson and E. Aberg (1991). "Treatment co-operation in orthodontic patients." Br J Orthod 18(1): 37-42.

Braun, S., H. P. Bantleon, W. P. Hnat, J. W. Freudenthaler, M. R. Marcotte and B. E. Johnson (1995). "A study of bite force, part 1: Relationship to various physical characteristics." Angle Orthod 65(5): 367-372.

Burden, D. J. (1995). "An investigation of the association between overjet size, lip coverage, and traumatic injury to maxillary incisors." Eur J Orthod 17(6): 513-517.

Burhardt, L., C. Livas, W. Kerdijk, W. J. van der Meer and Y. Ren (2016). "Treatment comfort, time perception, and preference for conventional and digital impression techniques: A comparative study in young patients." Am J Orthod Dentofacial Orthop 150(2): 261-267.

Burke, C. (2015). "A century of influence: Part 1. Orthodontic pioneers." Am J Orthod Dentofacial Orthop 147(5 Suppl): S155-160.

Burke, C. (2015). "A century of influence: Part 2. The greatest generation." Am J Orthod Dentofacial Orthop 148(2): 226-230.

Burke, C. (2015). "A century of influence: part 3. The modern era." Am J Orthod Dentofacial Orthop 148(5): 728-731.

Caliskan, M. K. and M. Turkun (1995). "Clinical investigation of traumatic injuries of permanent incisors in Izmir, Turkey." Endod Dent Traumatol 11(5): 210-213.

Calvert, F. J. (1982). "An assessment of Andresen therapy on class II division 1 malocclusion." Br J Orthod 9(3): 149-153.

Carels, C. and F. P. van der Linden (1987). "Concepts on functional appliances' mode of action." Am J Orthod Dentofacial Orthop 92(2): 162-168.

Carels, C. and D. van Steenberghe (1986). "Changes in neuromuscular reflexes in the masseter muscles during functional jaw orthopedic treatment in children." Am J Orthod Dentofacial Orthop 90(5): 410-419.

Casutt, C., H. Pancherz, M. Gawora and S. Ruf (2007). "Success rate and efficiency of activator treatment." Eur J Orthod 29(6): 614-621.

Cohen, A. M. (1981). "A study of class II division 1 malocclusions treated by the Andresen appliance." Br J Orthod 8(3): 159-163.

Cozza, P., T. Baccetti, L. Franchi, L. De Toffol and J. A. McNamara, Jr. (2006). "Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review." Am J Orthod Dentofacial Orthop 129(5): 599.e591-512; discussion e591-596.

Cozza, P., L. De Toffol and S. Colagrossi (2004). "Dentoskeletal effects and facial profile changes during activator therapy." Eur J Orthod 26(3): 293-302.

Cozza, P., L. De Toffol and L. Iacopini (2004). "An analysis of the corrective contribution in activator treatment." Angle Orthod 74(6): 741-748.

Crawford, T. P. (1974). "A multiple regression analysis of patient cooperation during orthodontic treatment." Am J Orthod

65(4): 436-437.

Curtis, J. R. (1998). "The "patient-centered" outcomes of critical care: what are they and how should they be used?" New Horiz 6(1): 26-32.

Das, U. M. and D. Reddy (2010). "Treatment effects produced by preorthodontic trainer appliance in patients with class II division I malocclusion." J Indian Soc Pedod Prev Dent 28(1): 30-33.

Den, A. M. (1994). "fenomenografiska forskningsansatsens fokus (The phenomenographic research approach in focus)." Kvalitativ metod och vetenskapsteori (Qualitative Method and Scientific Theory): 111-132.

Dermaut, L. R. and C. M. Aelbers (1996). "Orthopedics in orthodontics: Fiction or reality. A review of the literature--Part II." Am J Orthod Dentofacial Orthop 110(6): 667-671.

Dimberg, L., K. Arnrup and L. Bondemark (2015). "The impact of malocclusion on the quality of life among children and adolescents: a systematic review of quantitative studies." Eur J Orthod 37(3): 238-247.

Drage, K. J. and N. P. Hunt (1990). "Overjet relapse following functional appliance therapy." Br J Orthod 17(3): 205-213.

Drummond, M. F., B. J. O'Brien, G. L. Stoddart and G. W. Torrance (1997). Methods for the economic evaluation of health care programmes. Oxford, Oxford University Press.

Emine, K., T. Lale and G. Kahraman (2015). "Distribution of sagittal occlusal relationships in different stages of dentition." Braz Oral Res 29.

Espeland, L. V. and A. Stenvik (1991). "Orthodontically treated young adults: awareness of their own dental arrangement." Eur J Orthod 13(1): 7-14.

Farronato, G., L. Giannini, G. Galbiati, E. Grillo and C. Maspero (2013). "Occlus-o-Guide(R) versus Andresen activator appliance: neuromuscular evaluation." Prog Orthod 14: 4.

Feldmann, I., F. Lundstrom and S. Peck (1999). "Occlusal changes from adolescence to adulthood in untreated patients with Class II Division 1 deepbite malocclusion." Angle Orthod 69(1): 33-38.

Flores-Mir, C. and P. W. Major (2006). "A systematic review of cephalometric facial soft tissue changes with the Activator and Bionator appliances in Class II division 1 subjects." Eur J Orthod 28(6): 586-593.

Follin, M. E., E. Kahnberg and O. Sjostrom (1993). "Assessing the costs of activator treatments in general practice." Br J Orthod 20(3): 235-240.

Ghafari, J., F. S. Shofer, U. Jacobsson-Hunt, D. L. Markowitz and L. L. Laster (1998). "Headgear versus function regulator in the early treatment of Class II, division 1 malocclusion: a randomized clinical trial." Am J Orthod Dentofacial Orthop 113(1): 51-61.

Gross, A. M., G. Samson, S. Sanders and C. Smith (1988). "Patient noncompliance: are children consistent?" Am J Orthod Dentofacial Orthop 93(6): 518-519.

Hacker, T., G. Heydecke and D. R. Reissmann (2015). "Impact of procedures during prosthodontic treatment on patients' perceived burdens." J Dent 43(1): 51-57.

Harris, E. F. and M. G. Johnson (1991). "Heritability of craniometric and occlusal variables: a longitudinal sib analysis." Am J Orthod Dentofacial Orthop 99(3): 258-268.

Harrison, J. E. (2003). "Clinical trials in orthodontics I: demographic details of clinical trials published in three orthodontic journals between 1989 and 1998." J Orthod 30(1): 25-30; discussion 21.

Harvold, E. P. and K. Vargervik (1971). "Morphogenetic response to activator treatment." Am J Orthod 60(5): 478-490.

Hedlund, C. and I. Feldmann (2016). "Success rate, costs and long-term stability of treatment with activator/headgear combinations." Swed Dent J 40(1): 67-77.

Helm, S. (1968). "Malocclusion in Danish children with adolescent dentition: an epidemiologic study." Am J Orthod 54(5): 352-366.

Helm, S., S. Kreiborg and B. Solow (1985). "Psychosocial implications of malocclusion: A 15-year follow-up study in 30-year-old Danes." American Journal of Orthodontics 87(2): 110-118.

Hirzel, H. C. and J. M. Grewe (1974). "Activators: a practical approach." Am J Orthod 66(5): 557-570.

Holmes, A. (1992). "The prevalence of orthodontic treatment need." Br J Orthod 19(3): 177-182.

Idris, G., M. Y. Hajeer and A. Al-Jundi (2012). "Acceptance and discomfort in growing patients during treatment with two functional appliances: a randomised controlled trial." Eur J Paediatr Dent 13(3): 219-224.

Ingervall, B. and C. Minder (1997). "Correlation between maximum bite force and facial morphology in children." Angle Orthod 67(6): 415-422; discussion 423-414.

Ingervall, B., L. Seeman and B. Thilander (1972). "Frequency of malocclusion and need of orthodontic treatment in 10-year old children in Gothenburg." Sven Tandlak Tidskr 65(1): 7-21.

Janson, G., C. Caffer Dde, J. F. Henriques, M. R. de Freitas and L. S. Neves (2004). "Stability of Class II, division 1 treatment with the headgear-activator combination followed by the edgewise appliance." Angle Orthod 74(5): 594-604.

Janson, G., J. E. de Souza, M. R. de Freitas, J. F. Henriques and C. T. Cavalcanti (2004). "Occlusal changes of Class II malocclusion treatment between Frankel and the eruption guidance appliances." Angle Orthod 74(4): 521-525.

Janson, G., A. Nakamura, K. Chiqueto, R. Castro, M. R. de Freitas and J. F. Henriques (2007). "Treatment stability with the eruption guidance appliance." Am J Orthod Dentofacial Orthop 131(6): 717-728.

Janson, G. R., C. C. da Silva, E. O. Bergersen, J. F. Henriques and A. Pinzan (2000). "Eruption Guidance Appliance effects in the treatment of Class II, Division 1 malocclusions." Am J Orthod Dentofacial Orthop 117(2): 119-129.

Janson, G. R., A. C. Pereira, E. O. Bergersen, J. F. Henriques, A. Pinzan and R. R. de Almeida (1997). "Cephalometric evaluation of the eruption guidance appliance in Class II, division 1 treatment." J Clin Orthod 31(5): 299-306.

Jarvinen, S. (1978). "Incisal overjet and traumatic injuries to upper permanent incisors. A retrospective study." Acta Odontol Scand 36(6): 359-362.

Johal, A., M. Y. Cheung and W. Marcene (2007). "The impact of two different malocclusion traits on quality of life." Br Dent J 202(2): E2.

Johannsdottir, B., F. Thorarinsson, A. Thordarson and T. E. Magnusson (2005). "Heritability of craniofacial characteristics between parents and offspring estimated from lateral cephalograms." Am J Orthod Dentofacial Orthop 127(2): 200-207; quiz 260-201.

Josefsson, E., K. Bjerklin and R. Lindsten (2007). "Malocclusion frequency in Swedish and immigrant adolescents--influence of origin on orthodontic treatment need." Eur J Orthod 29(1): 79-87.

Kaakko, T., M. T. Horn, P. Weinstein, E. Kaufman, P. Leggott and S. E. Coldwell (2003). "The influence of sequence of impressions on children's anxiety and discomfort." Pediatr Dent 25(4): 357-364.

Katsavrias, E. G. and D. J. Halazonetis (1999). "Intermaxillary forces during activator treatment." Am J Orthod Dentofacial Orthop 115(2): 133-137.

Kavaliauskiene, A., D. Smailiene, I. Buskiene and D. Keriene (2012). "Pain and discomfort perception among patients undergoing orthodontic treatment: results from one month follow-up study." Stomatologija 14(4): 118-125.

Keeling, S. D., T. T. Wheeler, G. J. King, C. W. Garvan, D. A. Cohen, S. Cabassa, S. P. McGorray and M. G. Taylor (1998). "Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear." Am J Orthod Dentofacial Orthop 113(1): 40-50.

Kerosuo, H., H. Hausen, T. Laine and W. C. Shaw (1995). "The influence of incisal malocclusion on the social attractiveness of young adults in Finland." Eur J Orthod 17(6): 505-512.

Keski-Nisula, K., R. Hernesniemi, M. Heiskanen, L. Keski-Nisula and J. Varrela (2008). "Orthodontic intervention in the early mixed dentition: a prospective, controlled study on the effects of the eruption guidance appliance." Am J Orthod Dentofacial Orthop 133(2): 254-260; quiz 328. e252.

Keski-Nisula, K., L. Keski-Nisula, H. Salo, K. Voipio and J. Varrela (2008). "Dentofacial changes after orthodontic intervention with eruption guidance appliance in the early mixed dentition." Angle Orthod 78(2): 324-331.

Kiliaridis, S., H. Kjellberg, B. Wenneberg and C. Engstrom (1993). "The relationship between maximal bite force, bite force endurance, and facial morphology during growth. A cross-sectional study." Acta Odontol Scand 51(5): 323-331.

Kiliaridis, S., C. M. Mills and G. S. Antonarakis (2010). "Masseter muscle thickness as a predictive variable in treatment outcome of the twin-block appliance and masseteric thickness changes during treatment." Orthod Craniofac Res 13(4): 203-213.

King, G. J., S. P. McGorray, T. T. Wheeler, C. Dolce and M. Taylor (2003). "Comparison of peer assessment ratings (PAR) from 1-phase and 2-phase treatment protocols for Class II malocclusions." Am J Orthod Dentofacial Orthop 123(5): 489-496.

Kingsley, N. W. (1881). Die Anomalien der Zahnstellung und die Defecte des Gaumens. Leipzig, Verlag von Arthur Felix.

Kleinerman, V. and E. O. Bergersen (2011). "Preventive and interceptive orthodontics for the 5 to 12 year-old. Functional appliances: the Nite-Guide and Occlus-o-Guide techniques." Refuat Hapeh Vehashinayim 28(2): 8-18, 72.

Koretsi, V., V. F. Zymperdikas, S. N. Papageorgiou and M. A. Papadopoulos (2015). "Treatment effects of removable functional appliances in patients with Class II malocclusion: a systematic review and meta-analysis." Eur J Orthod 37(4): 418-434.

Koroluk, L. D., J. F. Tulloch and C. Phillips (2003). "Incisor trauma and early treatment for Class II Division 1 malocclusion." Am J Orthod Dentofacial Orthop 123(2): 117-125; discussion 125-116.

Krefting, L. (1991). "Rigor in qualitative research: the assessment of trustworthiness." The American journal of occupational therapy. : official publication of the American Occupational Therapy Association 45(3): 214-222.

Krooks, L., P. Pirttiniemi, G. Kanavakis and R. Lahdesmaki (2016). "Prevalence of malocclusion traits and orthodontic treatment in a Finnish adult population." Acta Odontol Scand 74(5): 362-367.

Kumar, S., A. C. Williams and J. R. Sandy (2006). "How do we evaluate the economics of health care?" Eur J Orthod 28(6): 513-519.

Kvale, S. (1996). "Interviews: An introduction to qualitative research interviewing." Interviews: An Introduction to Qualitative Research Interviewing.

Lepp, M. and K. C. Ringsberg (2002). "Phenomenography - A qualitative research approach." Qualitative Methods in Public Health Research: Theoretical Foundations and Practical Examples: 105-135.

Mandall, N. A., J. F. McCord, A. S. Blinkhorn, H. V. Worthington and K. D. O'Brien (2000). "Perceived aesthetic impact of malocclusion and oral self-perceptions in 14-15-year-old Asian and Caucasian children in greater Manchester." Eur J Orthod 22(2): 175-183.

Marton, F. (1981). "Phenomenography - Describing conceptions of the world around us." Instructional Science 10(2): 177-200.

Marton, F. (1986). "Phenomenography - A research approach to investigating different understandings of reality." Journal of Thought 21(3): 28-49.

McNamara, J. A., Jr. (1981). "Components of class II malocclusion in children 8-10 years of age." Angle Orthod 51(3): 177-202.

McNamara, J. A., Jr. and D. S. Carlson (1979). "Quantitative analysis of temporomandibular joint adaptations to protrusive function." Am J Orthod 76(6): 593-611.

Mi, C. B., X. L. Fan, Y. Tian, L. Peng and H. Guo (2003). "[The prevalence of orthodontic treatment need in Urumqi Han's adolescent]." Shanghai Kou Qiang Yi Xue 12(1): 11-13.

Migliaccio, S., V. Aprile, S. Zicari and A. Grenci (2014). "Eruption guidance appliance: a review." Eur J Paediatr Dent 15(2): 163-166.

Mollov, N. D., S. J. Lindauer, A. M. Best, B. Shroff and E. Tufekci (2010). "Patient attitudes toward retention and perceptions of treatment success." Angle Orthod 80(4): 468-473.

Myrlund, R., M. Dubland, K. Keski-Nisula and H. Kerosuo (2015). "One year treatment effects of the eruption guidance appliance in 7- to 8-year-old children: a randomized clinical trial." Eur J Orthod 37(2): 128-134.

Nanda, R. S. and M. J. Kierl (1992). "Prediction of cooperation in orthodontic treatment." Am J Orthod Dentofacial Orthop 102(1): 15-21.

Nguyen, Q. V., P. D. Bezemer, L. Habets and B. Prahl-Andersen (1999). "A systematic review of the relationship between overjet size and traumatic dental injuries." Eur J Orthod 21(5): 503-515.

Nilsson, J. J., X. Shu, B. H. Magnusson and I. A. Burt (2016). "Treatment of adolescent patients with class II division 1 malocclusion using Eruption guidance appliance: A comparative study with Twin-block and Activator-Headgear appliances." Swed Dent J 40(1): 79-89.

Noro, T., K. Tanne and M. Sakuda (1994). "Orthodontic forces exerted by activators with varying construction bite heights." Am J Orthod Dentofacial Orthop 105(2): 169-179.

O'Brien, K., J. Wright, F. Conboy, S. Chadwick, I. Connolly, P. Cook, D. Birnie, M. Hammond, N. Harradine, D. Lewis, C. McDade, L. Mitchell, A. Murray, J. O'Neill, M. Read, S. Robinson, D. Roberts-Harry, J. Sandler, I. Shaw and N. W. Berk (2003). "Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicenter, randomized, controlled trial. Part 2: Psychosocial effects." Am J Orthod Dentofacial Orthop 124(5): 488-494; discussion 494-485.

O'Brien, K., J. Wright, F. Conboy, Y. Sanjie, N. Mandall, S. Chadwick, I. Connolly, P. Cook, D. Birnie, M. Hammond, N. Harradine, D. Lewis, C. McDade, L. Mitchell, A. Murray, J. O'Neill, M. Read, S. Robinson, D. Roberts-Harry, J. Sandler and I. Shaw (2003). "Effectiveness of treatment for Class II malocclusion with the Herbst or twin-block appliances: a randomized, controlled trial." Am J Orthod Dentofacial Orthop 124(2): 128-137.

O'Brien, K., J. Wright, F. Conboy, Y. Sanjie, N. Mandall, S. Chadwick, I. Connolly, P. Cook, D. Birnie, M. Hammond, N. Harradine, D. Lewis, C. McDade, L. Mitchell, A. Murray, J. O'Neill, M. Read, S. Robinson, D. Roberts-Harry, J. Sandler and I. Shaw (2003). "Effectiveness of early orthodontic treatment with the twin-block appliance: A multicenter, randomized, controlled trial. Part 1: Dental and skeletal effects." American Journal of Orthodontics and Dentofacial Orthopedics 124(3): 234-243.

Oldin, A., J. Lundgren, M. Nilsson, J. G. Noren and A. Robertson (2015). "Traumatic dental injuries among children aged 0-17 years in the BITA study - a longitudinal Swedish multicenter study." Dent Traumatol 31(1): 9-17.

Ormiston, J. P., G. J. Huang, R. M. Little, J. D. Decker and G. D. Seuk (2005). "Retrospective analysis of long-term stable and unstable orthodontic treatment outcomes." Am J Orthod Dentofacial Orthop 128(5): 568-574; quiz 669.

Pacha, M. M., P. S. Fleming and A. Johal (2015). "A comparison of the efficacy of fixed versus removable functional appliances in children with Class II malocclusion: A systematic review." Eur J Orthod.

Pancherz, H. (1976). "Long-term effects of activator (Andresen appliance) treatment. A clinical, biometric, cephalometric roentgenographic and functional analysis." Odontol Revy Suppl 35: 1-70.

Pancherz, H. (1979). "Treatment of class II malocclusions by jumping the bite with the Herbst appliance. A cephalometric investigation." Am J Orthod 76(4): 423-442.

Pancherz, H., K. Zieber and B. Hoyer (1997). "Cephalometric characteristics of Class II division 1 and Class II division 2 malocclusions: a comparative study in children." Angle Orthod 67(2): 111-120.

Patton, M. Q. (1990). Qualitative Evaluation and Research Methods(3rd edit. London).

Petrén, S., K. Bjerklin, A. Ecorcheville and P. Hedrén (2014). "Orthodontic treatment by general practitioners in consultation with orthodontists - A survey of appliances recommended by Swedish orthodontists." Swedish Dental Journal 38(3): 121-132.

Proffit, W. R. and H. W. Fields (1983). "Occlusal forces in normal- and long-face children." J Dent Res 62(5): 571-574.

Proffit, W. R., H. W. Fields, Jr. and L. J. Moray (1998). "Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey." Int J Adult Orthodon Orthognath Surg 13(2): 97-106.

Proffit, W. R., H. W. Fields and D. M. Sarver (2013). Contemporary orthodontics. St. Louis, Mo, Elsevier/Mosby.

Raadsheer, M. C., S. Kiliaridis, T. M. Van Eijden, F. C. Van Ginkel and B. Prahl-Andersen (1996). "Masseter muscle thickness in growing individuals and its relation to facial morphology." Arch Oral Biol 41(4): 323-332.

Rabie, A. B., T. T. She and U. Hagg (2003). "Functional appliance therapy accelerates and enhances condylar growth." Am J Orthod Dentofacial Orthop 123(1): 40-48.

Rizell, S., B. Svensson, C. Tengstrom and H. Kjellberg (2006). "Functional appliance treatment outcome and need for additional orthodontic treatment with fixed appliance." Swed Dent J 30(2): 61-68.

Ruf, S. and H. Pancherz (1996). "The effect of Herbst appliance treatment on the mandibular plane angle: a cephalometric roentgenographic study." Am J Orthod Dentofacial Orthop 110(2): 225-229.

Sahm, G., A. Bartsch and E. Witt (1990). "Micro-electronic monitoring of functional appliance wear." Eur J Orthod 12(3): 297-301.

Sandelowski, M. (1986). "The problem of rigor in qualitative research." ANS. Advances in nursing science 8(3): 27-37.

Schafer, K., B. Ludwig, H. Meyer-Gutknecht and T. C. Schott (2015). "Quantifying patient adherence during active orthodontic treatment with removable appliances using microelectronic wear-time documentation." Eur J Orthod 37(1): 73-80.

Schmuth, G. P. (1983). "Milestones in the development and practical application of functional appliances." Am J Orthod 84(1): 48-53.

Schott, T. C. and G. Goz (2010). "Young patients' attitudes toward removable appliance wear times, wear-time instructions and electronic wear-time measurements--results of a questionnaire study." J Orofac Orthop 71(2): 108-116.

Schott, T. C. and B. Ludwig (2014). "Microelectronic wear-time documentation of removable orthodontic devices detects heterogeneous wear behavior and individualizes treatment planning." Am J Orthod Dentofacial Orthop 146(2): 155-160.

Schott, T. C., H. Meyer-Gutknecht, N. Mayer, J. Weber and K. Weimer (2016). "A comparison between indirect and objective wear-time assessment of removable orthodontic appliances." Eur J Orthod.

Seehra, J., P. S. Fleming, T. Newton and A. T. DiBiase (2011). "Bullying in orthodontic patients and its relationship to malocclusion,self-esteem and oral health-related quality of life." J Orthod 38(4): 247-256; quiz 294.

Seehra, J., J. T. Newton and A. T. DiBiase (2011). "Bullying in schoolchildren - its relationship to dental appearance and psychosocial implications: an update for GDPs." Br Dent J 210(9): 411-415.

Sepanian, V. F., L. Paulsson-Björnsson and H. Kjellberg (2014). "A long-term controlled follow-up study of objective treatment need on young adults treated with functional appliances." Swed Dent J 38(1): 39-46.

Sergl, H. G., U. Klages and A. Zentner (1998). "Pain and discomfort during orthodontic treatment: causative factors and effects on compliance." Am J Orthod Dentofacial Orthop 114(6): 684-691.

Sergl, H. G., U. Klages and A. Zentner (2000). "Functional and social discomfort during orthodontic treatment--effects on compliance and prediction of patients' adaptation by personality variables." Eur J Orthod 22(3): 307-315.

Sergl, H. G. and A. Zentner (1998). "A comparative assessment of acceptance of different types of functional appliances." Eur J Orthod 20(5): 517-524.

Shaw, W. C. (1981). "The influence of children's dentofacial appearance on their social attractiveness as judged by peers and lay adults." Am J Orthod 79(4): 399-415.

Shaw, W. C., S. C. Meek and D. S. Jones (1980). "Nicknames, teasing, harassment and the salience of dental features among school children." Br J Orthod 7(2): 75-80.

Shaw, W. C., G. Rees, M. Dawe and C. R. Charles (1985). "The influence of dentofacial appearance on the social attractiveness of young adults." Am J Orthod 87(1): 21-26.

Shenton, A. K. (2004). "Strategies for ensuring trustworthiness in qualitative research projects." Education for Information 22(2): 63-75.

Silveira, M. F., R. S. Freire, M. O. Nepomuceno, A. M. Martins and L. F. Marcopito (2016). "Severity of malocclusion in adolescents: populational-based study in the north of Minas Gerais, Brazil." Rev Saude Publica 50: 11.

Sjöström, B. and L. O. Dahlgren (2002). "Applying phenomenography in nursing research." Journal of Advanced Nursing 40(3): 339-345.

Slakter, M. J., J. E. Albino, R. N. Fox and E. A. Lewis (1980). "Reliability and stability of the orthodontic patient cooperation scale." American Journal of Orthodontics 78(5): 559-563.

Smith, R. J. and H. L. Balit (1977). "Problems and methods in research on the genetics of dental occlusion." Angle Orthod 47(1): 65-77.

Sollenius, O., S. Petren, L. Bjornsson, A. Norlund and L. Bondemark (2016). "Health economic evaluations in orthodontics: a systematic review." Eur J Orthod 38(3): 259-265.

Stewart, F. N., W. J. Kerr and P. J. Taylor (1997). "Appliance wear: the patient's point of view." Eur J Orthod 19(4): 377-382.

Taghavi Bayat, J., U. Hallberg, F. Lindblad, J. Huggare and B. Mohlin (2013). "Daily life impact of malocclusion in Swedish adolescents: a grounded theory study." Acta Odontol Scand 71(3-4): 792-798.

Taghavi Bayat, J., J. Huggare, B. Mohlin and N. Akrami (2016). "Predicting orthodontic treatment need: reliability and validity of the Demand for Orthodontic Treatment Questionnaire." Eur J Orthod.

The Swedish Council on Technology Assessment in Health Care (2005). Malocclusions and orthodontics in a health perspective: A systematic review of the literature. Report. Stockholm, Sweden. 176.

Thilander, B. (2009). "Dentoalveolar development in subjects with normal occlusion. A longitudinal study between the ages of 5 and 31 years." Eur J Orthod 31(2): 109-120.

Thilander, B. and N. Myrberg (1973). "The prevalence of malocclusion in Swedish schoolchildren." Scand J Dent Res 81(1): 12-21.

Thilander, B., M. Persson and U. Adolfsson (2005). "Roentgen-cephalometric standards for a Swedish population. A longitudinal study between the ages of 5 and 31 years." Eur J Orthod 27(4): 370-389.

Thiruvenkatachari, B., J. Harrison, H. Worthington and K. O'Brien (2015). "Early orthodontic treatment for Class II malocclusion reduces the chance of incisal trauma: Results of a Cochrane systematic review." Am J Orthod Dentofacial Orthop 148(1): 47-59.

Thiruvenkatachari, B., J. E. Harrison, H. V. Worthington and K. D. O'Brien (2013). "Orthodontic treatment for prominent upper front teeth (Class II malocclusion) in children." Cochrane Database Syst Rev 11: Cd003452.

Trulsson, U., L. Linlav, B. Mohlin and M. Strandmark (2004). "Age dependence of compliance with orthodontic treatment in children with large overjet. An interview study." Swed Dent J 28(2): 101-109.

Tsichlaki, A. and K. O'Brien (2014). "Do orthodontic research outcomes reflect patient values? A systematic review of randomized controlled trials involving children." Am J Orthod Dentofacial Orthop 146(3): 279-285.

Tulloch, J. F., W. Medland and O. C. Tuncay (1990). "Methods used to evaluate growth modification in Class II malocclusion." Am J Orthod Dentofacial Orthop 98(4): 340-347.

Tulloch, J. F., C. Phillips and W. R. Proffit (1998). "Benefit of early Class II treatment: progress report of a two-phase randomized clinical trial." Am J Orthod Dentofacial Orthop 113(1): 62-72, quiz 73-64.

Tulloch, J. F., W. R. Proffit and C. Phillips (1997). "Influences on the outcome of early treatment for Class II malocclusion." Am J Orthod Dentofacial Orthop 111(5): 533-542.

Twigge, E., R. M. Roberts, L. Jamieson, C. W. Dreyer and W. J. Sampson (2016). "The psycho-social impact of malocclusions and treatment expectations of adolescent orthodontic patients." Eur J Orthod 38(6): 593-601.

Twigge, E., R. M. Roberts, L. Jamieson, C. W. Dreyer and W. J. Sampson (2016). "Qualitative evaluation of pretreatment patient concerns in orthodontics." Am J Orthod Dentofacial Orthop 150(1): 49-57.

Usumez, S., T. Uysal, Z. Sari, F. A. Basciftci, A. I. Karaman and E. Guray (2004). "The effects of early preorthodontic trainer treatment on Class II, division 1 patients." Angle Orthod 74(5): 605-609.

Vargervik, K. and E. P. Harvold (1985). "Response to activator treatment in Class II malocclusions." American Journal of Orthodontics 88(3): 242-251.

Wheeler, T. T., S. P. McGorray, C. Dolce, M. G. Taylor and G. J. King (2002). "Effectiveness of early treatment of Class II malocclusion." Am J Orthod Dentofacial Orthop 121(1): 9-17.

Williams, S. and B. Melsen (1982). "Condylar development and mandibular rotation and displacement during activator treatment. An implant study." Am J Orthod 81(4): 322-326.

Wins, S. M., G. S. Antonarakis and S. Kiliaridis (2016). "Predictive factors of sagittal stability after treatment of Class II malocclusions." Angle Orthod 86(6): 1033-1041.

Woodside, D. G. (1973). "Some effects of activator treatment on the mandible and the midface." Trans Eur Orthod Soc: 443-447.

Woodside, D. G. (1998). "Do functional appliances have an orthopedic effect?" Am J Orthod Dentofacial Orthop 113(1): 11-14.

Woodside, D. G., A. Metaxas and G. Altuna (1987). "The influence of functional appliance therapy on glenoid fossa remodeling." American Journal of Orthodontics and Dentofacial Orthopedics 92(3): 181-198.

APPENDIX I, questionnaire

Appendix 1

Discomfort, expectations and experiences during treatment of large overjet with the Andresen activator or prefabricated functional appliance: a questionnaire survey

Survey Questions

1. How old are you?

   …….

2. What kind of appliance do you have?

   ☐ Myobrace

   ☐ Activator

3. Who suggested that you wear an orthodontic appliance? Write 1, for those who contributed most to you wearing an appliance, and 2, for the second most contributing person/persons.

   ☐ Me
   ☐ Mother
   ☐ Father
   ☐ Friend
   ☐ Dentist
   ☐ Someone else:_____

4. Has anyone noticed that your teeth are crooked?

   ☐ Yes Who? _____
   ☐ No

5. Have you ever been teased because of your teeth? Can you give examples of what was said?

   ☐ Yes Eg: _____
   ☐ No

6. Which of the following statements are correct regarding your treatment need?

My teeth will look better:

Disagree Strongly agree
I----------I

The risk of damaging my teeth will be less:

Disagree Strongly agree

I----------I

It will be easier to bite/chew food:

Disagree Strongly agree

I----------I

It will help keep my teeth healthy:

Disagree Strongly agree

I----------I

7. Is there anything in your teeth's position that you are unhappy about?
   If yes, please describe what this is:
   _____

   _____

8. Have there been any problems with appliance wear?

   It made my teeth hurt:

   Not at all Very much
   I----------I

   I had difficulties falling asleep:

   Never Often
   I----------I

   The appliance fell out during sleep:

   Never Often
   I----------I

The appliance was a barrier to contacts with other people:

Seldom/ never Often
I----------I

Difficult to remember to use the appliance:

Never Often
I----------I

Other problems: _____

Small Big
I----------I

9. Did you have any other kind of appliance? If yes, what kind?

□ Yes □ No

What kind?_____

10. What information did you receive regarding treatment problems that might occur? *(You can mark one or more options)*

- ☐ That my teeth will hurt during the first few days.
- ☐ That the appliance may fall out during sleep.
- ☐ That it may cause blisters.
- ☐ Other: _____

11. Did you receive useful information about the following?
(You can mark one or more options)

- ☐ The number of hours you must use the appliance.
- ☐ How to clean the appliance.
- ☐ What to do if the appliance breaks.
- ☐ What to do if the appliance repeatedly falls out during sleep.
- ☐ How long I will need to wear the appliance.
- ☐ What will happen if I'm careless with the use of the appliance.
- ☐ Other: _____