On Oral Health in Children and Adults with Myotonic Dystrophy

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UNIVERSITY OF GOTHENBURG

Gothenburg 2010

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Abstract

Background: Myotonic Dystrophy type 1 (DM1) is a hereditary neuromuscular multisystem disease with varying clinical expressions and severity. The prevalence worldwide is 5-20/100 000. It is characterized by progressive muscular waste and myotonia. Facial weakness is one of the earliest and most constant features. Muscular weakness has been shown to have an impact on oral health in various ways. The molecular basis for DM1 is an unstable trinucleotide (CTG) expansion on chromosome 19. The severity of the disease and time of onset is roughly correlated to the length of the CTG expansion.

Aim: The overall aim of this thesis is to shed light on oral health with focus on periodontal disease and caries in adults and children with DM1. Specific aims are: 1) To assess oral health and motoric ability in adults with DM. 2) To explore caries related factors including oral sugar clearance. 3) To assess oral health and dental care in children with DM1 and to evaluate the changes observed longitudinally over a four year period.

Subjects and Methods: In all, 27 adults, ages 35-64 years and 56 children, ages 2.7-18 years, and age and gender matched control persons were examined. Thirty-six of the children with DM and 33 of the control children were examined on two occasions about four years apart. Plaque, gingivitis caries and number of teeth were recorded. In the adult patients, finger force, oral muscular coordination ability, salivary secretion rate and oral sugar clearance were determined. In children, the ability to cooperate during dental treatment was estimated. Questionnaires concerning eating habits and dental care were also used.

Result: The adult and children DM1 patients had significantly more caries, plaque and gingivitis and had lost more permanent teeth than the control patients. This was particularly evident for the boys with DM1. Motoric ability, salivary secretion and oral sugar clearance showed less favorable mean values for the adult DM group than for the control group. A negative correlation was found between plaque index and finger force. The children with DM1 had a lower ability to cooperate than the controls and general sedation was often needed during dental treatment.

Conclusions: Adults and children with DM1 have more plaque, gingivitis and caries and have lost more teeth than age and gender-matched control persons. This may be explained by lower motoric ability, lower salivary secretion and slower oral sugar clearance and, in children, more cooperation problems. The differences between the groups remained or increased for children with DM1 over the four years in the longitudinal study. For these reasons, intensified prophylactic care, including easy home-care methods, is essential for patients with DM1 to firstly improve their oral health and secondly accustom DM1 children to the dental clinic and the treatment there.

Key words: Myotonic dystrophy, dental caries, gingivitis, dental care, oral sugar clearance, behavior management problems.
ISBN: 978-91-628-8024-8; ISSN: 0348-6672; http://hdl.handle.net/2077/21534

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Original papers

This thesis is based on the following papers, which will be referred to in the text by their Roman numerals:

I. **Engvall M, Kiliaridis S, Mejersjö C.** Dental needs of patients with myotonic dystrophy. *Swed Dent J.* 1991;15:171-8.

II. **Engvall M, Birkhed D.** Oral sugar clearance and other caries-related factors in patients with myotonic dystrophy. *Acta Odontol Scand*. 1997;55:111-5.

III. **Engvall M, Sjögreen L, Kjellberg H, Robertson A, Sundell S, Kiliaridis S.** Oral health in children and adolescents with myotonic dystrophy. *Eur J Oral Sci*. 2007;115:192-7.

IV. **Engvall M, Sjögreen L, Kjellberg H, Robertson A, Sundell S, Kiliaridis S.** Oral health status in a group of children and adolescents with myotonic dystrophy type 1 over a 4-year period. *Int J Paediatr Dent*. 2009;19:412-22.

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Abbreviations

ADHD	Attention Deficit / Hyperactivity Disorder
AUC	Area Under Curve
CNS	Central Nervous System
CP	Cerebral Palsy
CTG	Cytosine, Thymidine, Guanine (nucleotides)
def	Decayed, extracted (due to caries), filled teeth (t) or surfaces (s) of primary teeth.
DM	Myotonic dystrophy
DM1	Myotonic Dystrophy type 1
DM2	Myotonic Dystropy type II
DMD	Duchenne Muscular Dystrophy
DMPK	Myotonic Dystrophy Protein Kinase
DMF	Decayed, Missing (due to caries), Filled teeth (T) or surfaces (S), of permanent teeth.
DNA	Deoxyribonucleic acid
GBI	Gingival Bleeding Index
ICF	International Classification of Functioning, Disability and Health
MA	Motoric Ability
PROMM	Proximal Myotonic Myopathy
RF	Recognition of Forms
RNA	Ribonucleic acid
SiC	Significant Caries Index
WHO	World Health Organization
VPI	Visible Plaque Index

On Oral Health in Children and Adults with Myotonic Dystrophy

Introduction and background

Oral health is important for the well-being of all people, not least those with disabilities. It is important for nutrition and communication and improves self-esteem and quality of life. There are many parameters of oral health, but in this thesis, the focus is on two major oral diseases: Periodontal disease and caries.

The conditions for persons with disabilities to have good oral health have changed over time and vary across the world. Dental care in Sweden today is of excellent quality. The importance of prophylactic treatments has been recognized and fluoride is in common use. Different parameters of oral health have improved for the Swedish population. However, there are certain patient groups that, for various reasons, may not have followed the same development. Among them are persons with neuromuscular diseases.

Neuromuscular diseases constitute complex groups of heterogeneous, often inherited disorders. They can be broadly subdivided into disorders mainly affecting the anterior horn cells, peripheral nerves, neuromuscular junctions and the muscle fiber. Some multisystem disorders such as myotonic dystrophy (DM) and mitochondrial myopathies are traditionally also included (Darin & Tulinius, 2000).

Myotonic dystrophy

History

Myotonic dystrophy type 1 (DM1), dystrophia myotonica and myotonia atrophica are different names for a multisystem hereditary neuromuscular disease characterized by the combination of myotony with progressive muscle degeneration accompanied by various other symptoms. It is also called Steinert's disease after H. Steinert, who in 1909 was the first to present DM as a separate disorder (Steinert, 1909). In 1994, a different multisystem disease with similar symptoms was recognized, first named proximal myotonic myopathy (PROMM), but in 1999, the name was changed to myotonic dystrophy type 2. This disease has many symptoms in common with DM type 1 but differs in others, for example the pattern of muscular weakness, and has a different genetic locus. Perhaps the most important distinction is the lack of congenital or early onset cases, due to the type 2 mutation (Day *et al*., 1999, Harper, 2001).

Epidemiology

DM1 is one of the most common primary muscle diseases in adults. A worldwide prevalence of 5-20 per 100.000, apart from sub-Saharan Africa where it is virtually absent, is given by Harper (2001). Studies on linkage disequilibrium in DM1 suggest that a single ancestral mutation has been responsible for most cases of the disorder. This original mutation is to have taken place after a population had moved out of Africa, around 40.000 years ago. There are regions with a much higher prevalence, e.g. the Saguenay province in Quebec, Canada, and the northern parts of Sweden (Mathieu *et al*., 1990; Rolander & Flodérus, 1961). According to Örndahl *et al*. (1982), it is the most prevalent muscle disease among adults in the city of Gothenburg and its surroundings. In a recent study from western Sweden, the prevalence in

childhood was 5 per 100.000 (Darin & Tulinius, 2000). The incidence might even be higher since the disease, in its mildest form, is often not recognized (Harley *et al*., 1992). Moreover, there is strong evidence that many fatal cases of congenital myotonic dystrophy remain undiagnosed (Harper, 2001).

Genetics

DM1 is inherited as an autosomal dominant trait. Research in genetics and human molecular biology during the last two decades has yielded answers to many puzzling questions regarding DM1. The varying penetrance of the disease and the increasing severity and earlier age of onset in successive generations, so-called genetic anticipation, has now been explained. The genetic locus for DM1 on the long arm of chromosome 19 was localized in the late eighties (Shaw & Harper, 1989). A few years later, the molecular basis for DM1 was shown to be an unstable expansion of a trinucleotide (CTG) repeat (Brook *et al*., 1992; Fu *et al*., 1992; Harley *et al*., 1992; Mahadevan *et al*., 1992; Reardon & Harper, 1992). The tri-nucleotide repeat in DM1 is located in an untranslated region of the myotonic dystrophy protein kinase (DMPK) gene. The gene is highly expressed in the heart, muscles and to a lesser extent in the brain (Brook *et al*., 1992; Reardon & Harper, 1992). An association between the sites of DMPK expression and the tissues affected in DM1 is known, although the biochemical function still has to be fully characterized (Harper, 2001). There is an approximate correlation between the CTG trinucleotide insert size and both the severity of DM1 and the age at onset. The repeat length in the general population varies between 5 and 35 CTG repeats. DM1 patients inherit at least 50 repeats and in some cases as many as 2000 or more. The insert can be seen to lengthen in successive generations in the offspring of both affected males and females (Harper *et al*., 1992). Studies from Quebec and northern Sweden suggest that the mutated gene may pass through 15 generations or more without producing obvious effects (Mathieu *et al*., 1990; Harper *et al*., 1992; Harley *et al*., 1992).

Recent advances in molecular genetics have shed light on the pathophysiology of DM1. Three theories as to how a tri-nucleotide expansion in a non-coding region of the gene can cause the disease have been proposed: a) Haploinsufficiency of DMPK, b) Altered expression of neighboring genes or c) RNA toxicity (Ekström, 2009). "*The current model is that expression of RNA transcripts containing pathogenic repeat lengths produces defects in alternative splicing of multiple RNAs by sequestering repeat binding proteins, ultimately leading to the expression of splice products that are developmentally inappropriate for a particular tissue*" (Meola & Sansone, 2007).

Clinical picture

Before DNA diagnosis was developed in the 1990s, diagnosis of DM was made on the basis of inheritance patterns, the clinical picture, neurophysiologic investigations and biopsies of muscular tissues. DM was considered a multisystem disorder with a varying clinical picture. The dominant symptoms were the combination of myotonia, i.e. the inability to relax voluntary muscle contractions, and progressive muscle weakness, especially in the face and distal part of the limbs. Abnormalities in organ systems other than skeletal muscle include cardiac conduction defects, smooth muscle dysfunction, hypersomnia and cataracts. In males, balding and testicular atrophy, infertility and impotence were also recognized (Skoczylas *et al*., 1985; Harper 1989). Studies of biopsies from muscles of DM1 patients show varying changes. The most common histopathological changes found are muscle fibre atrophy, with small angular fibres, internal nuclei, muscle fiber splitting, fibrosis and "moth-eaten" fibers (Grimby *et al*., 1988).

The finding of the mutational defect in 1992 explained the large variation in the clinical picture. In 1994, after the recognition of PROMM, later called DM2, as a separate entity, the clinical picture is even clearer. Four forms of DM1 can now be discerned, with varying symptoms (Table I) (de Die Smulders, 2000; Koch 1999). A further division of the congenital type into a severe and a mild subgroup, according to the severity of symptoms at birth, is made by Kroksmark *et al*. (2005), and Ekström *et al*. (2008). In their classification, the number of CTG repeats varied between 730-2400 in the severe congenital subgroup, between 130-2100 in the mild congenital subgroup and between 260-1300 in the childhood onset type. The congenital type is almost exclusively maternally transmitted (Bergoffen *et al*., 1994). The diagnosis of DM1 in a family is often first made when a severely hypotonic child is born to a mother who does not know that she has the classical type of DM1. The advances in specific molecular diagnosis of DM1 have made it possible to more effectively counsel families affected by the disease and to identify individuals, particularly women, who are at risk of passing on the DM1 mutation (Harper & Brunner, 2004).

Type	Age at onset	Early symptoms	Later symptoms	Number of CTG repeats
Mild	>50	Cataract	Myotonia, mild weakness	40-80
Adult or classical	12-50	Myotonia muscle weakness	Increased weakness, cataract, slowness/apathy, organ complications	100->1000
Childhood	1-12	Learning difficulties, speech difficulties	Bowel problems, tiredness, myotonia, muscle weakness as in the adult type	500-> 2000
Congenital	Birth	Hypotonia, respiratory and swallowing problems, club feet	Learning and speech difficulties as in the childhood type	1000- >5000

Table I: The four forms of myotonic dystrophy, age at onset, most important early and later symptoms and number of CTG triplet repeats (after de Die Smulders 2000).

The distribution of weakness is relatively characteristic. Facial weakness with involvement of facial and jaw muscles, ptosis of the eyelids and weakness of the sternocleidomastoid muscles are among the earliest and most constant features (Harper, 2001). Hollowing of the temples is seen due to atrophy of the temporal muscle (Skoczylas *et al*., 1985; Harper, 2001). Atrophy and degeneration of the masseter muscle in patients with myotonic dystrophy have also been shown with ultrasound technique (Kiliaridis *et al*., 1995). There also tends to be involvement of distal muscles, such as those of the hand and foot, the extensors of the forearm and the anterior tibial muscle (Carpenter & Karpati, 1984; Harper,

2001). Atrophy and weakness of the pharyngeal muscle produce a nasal voice with poor enunciation and easy fatigue (Thayer & Crenshaw, 1966; Penarrocha *et al*., 1990). The nature of the smooth muscle involvement varies according to the stage of the disease. Swallowing difficulties occur in most patients (Skoczylas *et al*., 1985; Harper, 2001).

In congenital DM1, there is a variable degree of hypotonia in the immediate postnatal period, which in severe cases may necessitate assisted ventilation. The facial weakness (facial diplegia) gives a characteristic picture of tented lips. Weakness in the jaw and palate result in difficulties with sucking and swallowing. The hypotonia improves gradually but motoric function will later deteriorate as in the classical type of DM1 (Harper 2001, Kroksmark *et al*., 2005) In the childhood onset type, symptoms of the disease appear between 1 and 10 years of age as abdominal symptoms, variable degrees of learning difficulties and muscle hypotonia, including clumsiness (de Die Smulders, 2000). Indistinct speech and swallowing difficulties are described both in the congenital and childhood onset type of DM1 (Sjögreen *et al*., 2007).

Myotonia, the hallmark of DM1 as a clinical finding, is most marked in those patients with relatively minor muscle weakness and wasting, and may be difficult to elicit in advanced cases with severe wasting. In general, myotonia arises in late infancy whereas muscle atrophy develops between the ages of 20 and 30 years. Many patients are unable to remember the onset of myotonia, but claim to always have had problems in chewing, swallowing, or relaxing their hands (Harper, 2001; Penarrocha *et al*., 1990). Myotonia is best tested in the hand muscle where following a forceful grip, there is a delayed ability to relax the grip. Percussion of the tongue may cause a persistent dimpling of its surface (Skoczylas *et al*., 1985; Harper, 2001). Severe clinical problems arising from myotonia are rare and there is a remarkable lack of complaint by the patients concerning it (Harper, 2001).

Influence on the brain in DM1 results in intellectual impairment and emotional disorders (Antonini *et al*., 2006). In the childhood and congenital types, there is an obvious affect on CNS. Speech difficulties and neuropsychiatric disorders such as autism and attention deficit/hyperactivity disorder (ADHD) are common, as are learning disabilities (de Die Smulders, 2000; Harper, 2001; Ekström *et al*., 2008, 2009). In the classical adult type, there is an association with neurocognitive dysfunction, anomalies in personality and the reduced ability to recognize facial emotion (Winblad, 2006).

General trends in oral health

Periodontal disease

The most common periodontal diseases are gingivitis and chronic periodontitis (Caton *et al*., 1999; Linde *et al*., 1999). In both diseases, plaque is one of the etiological factors. Plaque induced gingivitis is restricted to the gingival tissues and the periodontium is stable, with no loss of periodontal attachment or alveolar bone (Mariotti, 1999). According to the current classification, chronic periodontal disease is "*an infectious disease resulting in inflammation within the supporting tissues of the teeth, progressive attachment and bone loss. It is characterized by pocket formation and/or gingival recession*" (Linde *et al*., 1999). According to Baelum (2007), most people in the world have gingivitis and calculus, but bleeding of the gingiva and calculus are not adequate indicators of periodontitis. There is a lack of agreement on what kind of criteria should be used in epidemiological studies (Hugoson & Norderyd, 2008). Therefore, there are too few scientific papers presented to allow more general conclusions on the epidemiology of periodontal disease worldwide. However, it seems that the prevalence of periodontal disease has decreased during the last thirty years in parts of Europe and the USA. This reported change is mainly in gingivitis and mild/moderate

periodontitis (Hugoson & Norderyd, 2008). Worldwide, however, there is still a widespread prevalence of plaque induced gingivitis and slight to moderate periodontitis while severe forms of periodontal disease affect only a subset of population groups (Albandar & Rams, 2002). According to Albandar & Tinoco (2002), there is a great disparity as to the prevalence of more severe forms of periodontitis among young people across the world. The low level of periodontitis among young populations in developed countries, particularly in northern and other west European countries, may be attributable to the provision of community based dental health systems, which in some countries are even free of charge.

In Sweden, the Jönköping studies showed that oral hygiene and periodontal health improved significantly in the 20-80 year age groups over a 30 year period from 1973-2003 (Hugoson *et al*., 2008). Compared to data from 1973, there was a reduction by half in the occurrence of plaque and gingivitis in 2003 in all studied age groups from 3-80 years. The comparison of the four Jönköping studies shows that there has been a great overall improvement in oral health over this 30-year period (Hugoson *et al*., 2005).

Caries

A decrease in the prevalence of dental caries has been demonstrated in the industrialized countries during the last decades. During this time, methods for prevention have improved and the use of fluoride increased. Some of the decrease of the dental caries may be attributed to changes in diagnostic criteria and treatment decisions. New treatment methods and dental materials could also lead to improvements in oral health status. According to WHO, however, dental caries is still a major problem in most industrialized countries with 60-90 % of school children and the vast majority of adults affected (Petersen *et al*., 2005; WHO 2007). In most developing countries, the levels of dental caries were low until recent years, but are now tending to increase with the increasing consumption of sugar containing products and inadequate exposure to fluorides (Petersen *et al*., 2005).

In Sweden, the Jönköping studies of 1973-2003 showed steadily improved dental health among most adolescents and the same trend was seen in adults (Hugoson & Koch, 2008). However, improvement was not seen in the primary dentition during the last 10 years of the study series (Hugoson *et al*., 2008). Data, from the Swedish National Board of Health and Welfare (2006), on caries prevalence in children and adolescents between the years 1985-2005, showed that improvements in prevalence continued but slowed down between the years 2000 and 2005. Similar results were reported from Norway, where in an analysis of prevalence in manifest caries in 12-year olds and incidence from 12 to 18 years of age, a decline from 1985 onwards was broken with an increasing trend seen between the years 2000 and 2004 (Haugefjorden & Birkeland, 2006). Significant caries index (SiC), that is the caries index for the third part of the population that has most caries, even has increased for the 12-year olds in Sweden since 1997. In contrast to this, findings from Umeå (Stecksén-Blicks *et al*., 2008) show an improvement in caries prevalence in four-year old children between the years 2002 and 2007 concurrently, with a decreased intake of sugary between meal products and increased tooth brushing frequency. A mutual effort to reduce obesity in children and to reduce dental caries, thus, may have proven successful.

Oral Health in disability

Classification

The International Classification of Functioning, Disability and Health, known more commonly as ICF, is a classification of health and health-related domains (WHO, 2001). The ICF is WHO's framework for measuring health and disability at both individual and population levels. Disability is an umbrella term covering impairments, activity limitations and participation restrictions. Impairment is a problem in body function or structure. Activity limitation is a difficulty encountered by an individual in executing a task or action. Participation restriction is a problem experienced by an individual in involvement in life situations. Thus, disability is a complex phenomenon reflecting an interaction between features of a person's body and features of the society in which he or she lives. By including Contextual Factors in which environmental factors are listed, ICF allows the recording of the impact the environment has on a person's functioning (WHO homepage for ICF).

According to WHO (WHO homepage for disability), around 650 million persons worldwide live with disabilities. As more people survive into old age, there is an increase in the volume of older people who are likely to develop a disability coincidental or consequential to ageing. More people with disabilities will survive into their fifties and sixties, facing the challenges of older life. Furthermore, improved pediatric care means that increasing numbers of children born with complex and multiple disabilities are surviving into adulthood (Gallagher & Fiske, 2007).

Oral manifestation of different disabilities

Oral health is often considered a probable source of health inequalities in persons with neuromotoric and mental deficiencies (Hennequin *et al*., 2008). The disability may incur difficulties in acquiring, accepting and financing dental treatment, maintaining good oral hygiene, side effects from medication, chewing and swallowing problems, influences on orofacial development and greater risk for caries and tooth loss (Nunn, 2000). Many persons with disabilities are wheelchair dependent and have difficulty visiting dental clinics. The fact that countries vastly differ in their oral health care systems is also an obstacle when considering the dental care persons with disabilities receive. Across the world, many individuals who previously would have been placed in large institutions are now living in small community group homes or with their families (Shenkin *et al*., 2001).

The influence of a disability on oral health depends on the characteristics of the disabling disease. In asthma, the effects of the medication may lead to increased caries prevalence and oral candida infections. Patients with Down's syndrome have problems with mouth breathing, periodontal disease, microdontia and hypodontia. Cerebral palsy (CP) may lead to dental trauma, malocclusion and drooling (Storhaug, 2000). Higher DMFT values in non-institutionalized young people with CP compared with non-disabled individuals of the same age also have been reported (dos Santos *et al*., 2002; Rodrigues dos Santos *et al*., 2009). Higher caries prevalence and behavior management problems have been reported in patients with attention deficit and hyperactivity disorder (ADHD) (Blomqvist *et al*., 2006).

In physical disabilities, the muscles and the ability to move are affected. Among the diseases with physical disability are the neuromuscular. Although the disorders have varying symptoms, most neuromuscular disorders will cause muscle weakness (Kroksmark, 2005). Muscular weakness has been shown to have an impact on oral health in various ways. It affects craniofacial growth (Kiliaridis *et al*., 1989; Staley *et al*., 1992) as well as chewing capacity, oral self-cleaning ability and oral sugar clearance (Swenander Lanke, 1957; Hase *et al*., 1987).

Orofacial manifestations of myotonic dystrophy

Studies on oral manifestations of DM are mostly concerned with the effect of the disease on craniofacial development. Those recognized as having DM at an early age exhibit aberrant facial growth. Weakened musculature and altered balance influence craniofacial morphology and occlusal development (Kiliaridis *et al*., 1989; Ertürk & Dogan, 1991). Persons with DM experience more vertical facial growth than normal subjects and have narrower maxillary arches and deeper palatal depths (Harper, 1989; Kiliaridis *et al*., 1989; Staley *et al*., 1992). Kiliaridis *et al*., (1989) found a high prevalence of malocclusions (such as distal occlusion, anterior open bite and lateral crossbite) among DM patients. This is in accordance with several other reports (Thayer & Crenshaw, 1966; Ghafari *et al*., 1988; Ertürk & Dogan, 1991). Gazit *et al*. (1987) also found greatly reduced strength of the orbicularis oris muscle, tongue thrust and mouth breathing. Temporomandibular dislocation, recurrent locking of the jaw and frequent clicks are well documented (Harper, 2001).

Difficulties in mastication and swallowing as symptoms of DM have been reported in many studies (Penarrocha *et al*., 1990; Hillarp *et al*., 1994; Kahrilas, 1994; Willig *et al*., 1994; Harper, 2001). Ödman & Kiliaridis (1996) showed that DM patients needed 2.5 times longer and 2.5 more chewing cycles than controls when chewing peanuts. On average, they had less than half the maximal bite force level of a healthy control group (Kiliaridis *et al*., 1989). Swallowing problems in DM1 are related to myotonia in masseteric muscles, weakness and atrophy of muscles, dryness of the mouth and, predominantly, difficulties in the posterior phase of swallowing, such as choking, repeated attempts to swallow, nasal reflex and regurgitation (Willig *et al*., 1994). Harper (2001) stressed the importance of weakness of the palate. Incompetence of the palate predisposes to aspiration of material into the bronchial tree, and together with involvement of the tongue and jaw, provides an abnormal start to the swallowing process. This may further be aggravated by involvement of the pharyngeal and oesophageal musculature (Harper, 2001). Sjögreen *et al*. (2007) reported that orofacial dysfunction, defined as impaired facial expression, reduced intelligibility, eating and drinking difficulties and drooling are common features in congenital and childhood DM1 compared to healthy peers.

There are very few reports (mostly case reports) on the cariological and periodontal situation in DM1 patients; no greater incidence of either of these two diseases was reported by White & Sackler (1954) and by Thayer & Crenshaw (1966). Severe periodontitis in a 52-year old man with DM1 was reported by Skoczylas *et al*. (1985), which was thought to be explained by the patient's decreased ability to handle a toothbrush and dental floss.

The knowledge of oral health in DM in terms of periodontal disease and dental caries in cross-sectional as well as longitudinal studies is lacking, especially in children. The knowledge of behavior management problems and physical limitations in individuals with DM and their acceptance of dental care are also lacking. The progressive character of the disease also gives rise to the question regarding the dental needs advocated for individuals with DM. Finally, it seems important that oral health programs and guidelines regarding the disease should be accurate in the dental care of individuals with DM.

Multiprofessional survey

The studies in this thesis were all parts of multiprofessional surveys. In the middle of the 1980's, Gustav Örndahl, Gunnar Grimby and co-workers at the medical faculty in Gothenburg examined a group of adult persons with the classical type of DM. That same group of patients also participated in studies at the Institute of Odontology in Gothenburg

initiated by Stavros Kiliaridis. They participated in the studies presented in Papers I and II in this thesis. Since the classification of DM1 and DM2 came later, this group will be referred to as DM.

Since children also are affected by DM1, questions arose whether it would be possible to prevent the deleterious effects of the disease, seen in previous studies on different parameters of oral health, through early intervention. In order to study this, contact was taken in the late 1990's with the Institution for Pediatric Neurology where projects concerning studies of neurological diseases in children had been on-going under the direction of Professor Mar Tulinius, with support from FOU, Västra Götaland. This led to a series of studies concerning myotonic dystrophy type 1 in children in the fields of odontology, speech and language pathology, physiotherapy, opthalmology, pediatric neurology, psychology and neuropsychiatry (Kroksmark *et al*., 2005; Sjögreen *et al*., 2007; 2008, Ekström *et al*., 2008; 2009; Engvall *et al*., 2007; 2009).

Aims

The overall aim of this thesis is to shed light on oral health in individuals with DM. The findings may lead to improved preventive measures for patients with this and similar diseases. The specific aims of the four studies were:

- To assess oral health and motoric ability in adult persons with DM in comparison with a control group.
- To explore caries related factors including oral sugar clearance in adult patients with DM.
- To assess oral health and dental care in children with congenital or early onset types of DM1 in comparison with a healthy control group.
- To evaluate longitudinally the changes observed in oral health during a four year period in a group of growing children with this progressive neuromuscular disease.

Subjects and Methods

Subjects

Adult patients (Studies I and II)

The study populations are presented in Figure 1. The DM patients in Study I participated in studies led by Grimby *et al*. (1988) and Örndahl *et al*. (1994). They comprised 18 women and nine men, the mean age 46 years (range 35-64) and constituted the vast majority of known DM cases in Gothenburg and its surrounding areas at that time. The control patients, age and gender matched, were recruited from the Public Dental Clinic at the Institute of Odontology in Gothenburg.

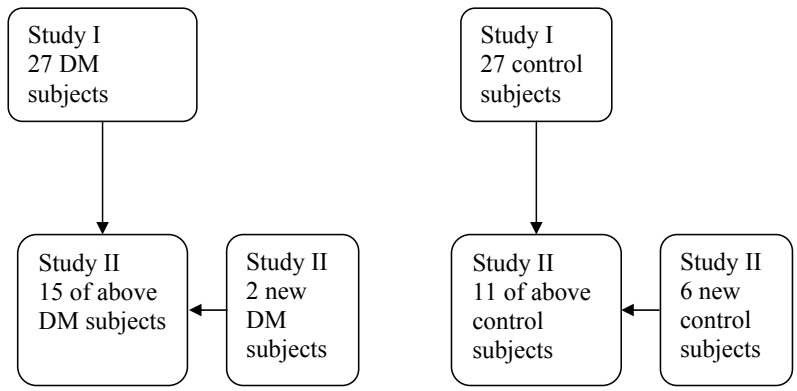

Figure 1. The adult population in Studies I and II.

In Study II eight years later, 15 of the DM patients and 11 of the control patients participated. Two new DM patients and six new control patients were enrolled. The mean age in the new DM group was 50 years (range 42-70 years) and in the new control group 49 years (range 36-68 years).

In the DM group in Study II, two subjects received a regular retirement pension, four received sickness benefits, two were out of work and five worked part-time, some in sheltered jobs. Four subjects gave no information regarding their work situation. In the control group, two subjects received regular retirement pensions, two received sickness benefits and the rest had ordinary jobs.

The reasons for not participating in Study II were as follows: In the DM group four individuals had died, three were hospitalized, one had moved from the region and four did not wish to participate. In the control group, two had died, one was hospitalized, four had moved from the region, four could not be reached and the rest did not wish to participate, mostly for lack of time.

Study I, and as a sequel, Study II were approved by the Ethical Committee in Gothenburg. Informed consent was obtained from each participant.

Children (Studies III and IV)

The study populations are presented in Figure 2 and Table II. All the children with DM1 participating in Study III (cross-sectional) and Study IV (longitudinal) were part of a multidisciplinary study of DM1 at the University of Gothenburg. Their diagnosis was confirmed by DNA analysis of blood samples. There was a range from 130 to 2300 CTG-repeats among the patients (Kroksmark *et al*. 2005).

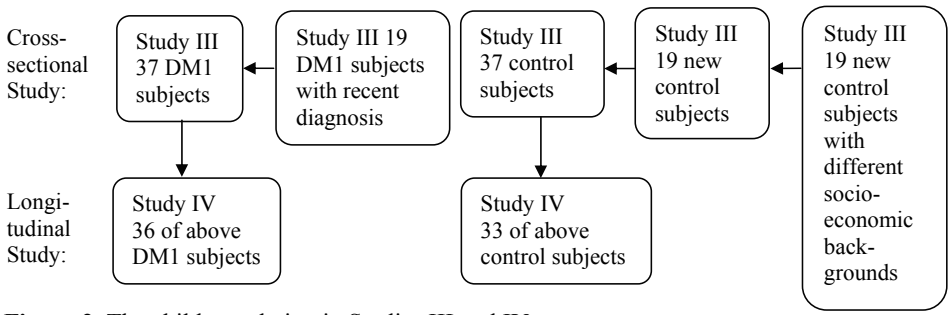

Figure 2. The child population in Studies III and IV.

	Age	Severe congenital	Mild congenital	Childhood	Classical
Study III					
Boys	2.7-17.7	13	8	9	0
Girls	3.1-18.0	4	10	10	2
Study IV					
Boys	7.8-21.6	8	6	8	
Girls	6.5-20.9	2	7	5	

Table II. Children and adolescents with DM1 according to type in Studies III and IV.

The patients were between 2.7 and 18.0 years of age in the cross-sectional study and constituted the vast majority (88 %) of diagnosed cases in this age group in the counties of Västra Götaland and Skåne, in the western and southern parts of Sweden. The children in the DM1 group were compared with a control group of healthy children matched for age and gender. These children were selected randomly among the children living in the up-take area of a public dental clinic in Gothenburg. In order to test the possible influence of socio-economic factors when comparing caries data, a complementary study was performed with an additional control group from a dental clinic with lower socio-economic status. The status is based on an index used at that time period in Gothenburg. Taken into account in different areas was the level of education, employment, the number of persons with an immigrant background or the receiving of social welfare, between the ages 16 to 65 years.

Of the original 37 patients in the longitudinal Study IV, one boy with DM1 had moved out of the area and could not participate in the second examination. Four control patients could not be examined, one boy declined participation, one boy was not reached and two girls had moved from the area.

Thirty of the DM1 patients went to special schools for children with learning disabilities and six went to ordinary schools. All control patients went to ordinary schools.

Studies III and IV were approved by the Ethical Committees of the Medical Faculties at Gothenburg and Lund Universities. Informed consent was obtained from each participant and/or the parents.

Methods

Anamnestic data and questionnaires

The different questionnaires used in the studies are listed in Table III. The Mun-H-Center (MHC) questionnaire and observation chart (Andersson-Norinder, 1996) are rather comprehensive with questions also regarding the frequency of visits to the dentist and if the child attended a specialist or public dental care clinic. Behavior management problems during dental treatment and the need for sedation or general anesthesia to carry out treatment were also assessed. An estimation of the ability to cooperate was made on a scale from zero (no problems) to ten (extreme difficulties) by the examiners and by the patient and/or parents. The patients and/or parents were also asked about satisfaction with the dental care received.

Subject	Questionnaire	Study
Dental care	Standard questionnaire on general health (RA 8102 89-10) used in the Public Dental Service in Göteborg	II
	Specific questionnaire on dental care, oral hygiene habits, use of fluorides, swallowing difficulties, mouth breathing and dry mouth	II
	MHC Questionnaire and Observation chart concerning eating habits, oral hygiene, dental care and orofacial function	III, IV
Diet	A questionnaire regarding intake frequency of 25 cariogenic food products. (LIC T-51 1983-06) The items were given a score according to the frequency of consumption. An individual dietary score was calculated by adding the scores for all 25 products.	II, III, IV

Table III. Questionnaires used in the studies. (MHC=Mun-H-Center)

Radiological and clinical examinations

Clinical examinations of caries and restorations in all studies were made in a dental office with optimal lighting and in Studies II, III and IV by the same examiner.

The adult patients were all examined in a clinic at the Institute of Odontology in Gothenburg, where also some of the examinations of children with DM1 from the vicinity of Gothenburg were made. However, the children with DM1 tired easily and long journeys for them were avoided. Therefore, most of the radiological and clinical examinations were performed in a dental clinic as close to where the child lived as possible, preferably the clinic

where he or she usually received dental care. For practical reasons, several children not living too far apart from each other were examined at one clinic, relatively close for them all.

Radiological examination
Bitewing radiographs and/or orthopantomographs were used for all adult patients. In the child group, it was not always necessary or possible to take radiographs on account of low age or refusal to cooperate. In Study III, bitewing radiographs and/or orthopantomographs were available or taken in 40 of 56 DM1 patients and in 44 of 56 control individuals. In Study IV, they were available or taken in 28 of 36 DM1 patients and 30 of 33 control individuals.

The films were examined using a magnifying viewer (Mattsson, 1953) and light desk.

Oral hygiene and periodontal disease
Adults: In both Studies I and II, a plaque index (Silness & Löe, 1964) was recorded on eight surfaces (mesial surface of first molars and distal surface of central incisors). On the same surfaces, gingival pockets ≥4 mm were recorded. If any of these teeth were missing, the same surface on the tooth closest was measured. The clinical recordings in Study I and II were made by one examiner, who was not the same in both studies.

In Study I, alveolar bone height was calculated by measuring the distance from the cemento-enamel junction to the alveolar bone crest on the bitewing radiographs, according to the method described by Björn *et al*. (1969), modified by Papapanou *et al*. (1988). The calculations were made by one examiner.

Children: In Studies III and IV, plaque and gingivitis were recorded according to the visible plaque index (VPI) and the gingival bleeding index (GBI), that is the percentage of surfaces with visible plaque or bleeding on probing, respectively, out of the total number of surfaces examined (Ainamo & Bay, 1975).

For both adults and children, information on oral hygiene habits was collected from the questionnaires.

Caries and restorations
The DMF, def system (Klein, 1946) was used for caries registration. The DMF indexes used in the studies are presented in Table IV.

In Study I, caries was recorded from orthopantomographs and bitewing radiographs. Only dentine caries was included. DMFT and proximal DMFSa and DFSa (in premolars and molars, excluding third molars) were recorded. DFS as a percent of the remaining proximal surfaces (in premolars and molars, excluding third molars) was also calculated (DFS%). The number of remaining teeth and pontics was registered on the orthopantomographs.

In Studies II, III and IV, caries and restorations were recorded clinically with mirror and probe according to criteria described by Koch (1967). In radiographs, proximal carious lesions within the enamel or just reaching the enamel-dentin border with no spread into the dentin were diagnosed as initial caries, and lesions with a clear spreading into the dentin as manifest caries.

In Study III, the comparison was made between the whole group of patients and healthy controls, and between the 20 percent of subjects with the highest caries experience.

In order to make a true longitudinal comparison of caries, in spite of age differences and number of teeth, a key tooth at risk, the first permanent molar, was selected for examination in Study IV. Comparison of caries index in this tooth was made when it was present at both

examinations. Calculation of increment of caries on occlusal, proximal, buccal and lingual surfaces between the two examinations was also made on the first and second permanent molars, when present at both examinations. Teeth that had erupted between examinations and were decayed at Examination 2 also were included in the indexes. Molar and premolar teeth, extracted due to caries, were recorded as five surfaces.

Index	Criteria	Study
DMFT	Number of decayed, missing and filled permanent teeth	I, II, III, IV
DMFS	Number of decayed, missing and filled permanent surfaces	II, III, IV
DMFSa	Number of decayed, missing and filled proximal permanent surfaces in premolars and molars excluding third molars	I
DMFSb	Number of decayed missing and filled buccal surfaces	IV
DFSa	Number of decayed and filled proximal permanent surfaces in premolars and molars excluding third molars	I, II
DFS%	DFS as a percent of remaining proximal surfaces in premolars and molars excluding third molars	I
deft	Number of decayed, extracted (due to caries) and filled primary teeth	III, IV
defs	Number of decayed, extracted (due to carries) and filled primary surfaces	III, IV
DS	Number of decayed permanent surfaces	III
ds	Number of decayed primary surfaces	III
DSi	Number of permanent surfaces with initial caries	III
DSi b	Number of buccal permanent surfaces with initial caries	IV
dsi	Number of primary surfaces with initial caries	III

Table IV. Caries indices used in the different studies.

Number of teeth
The number of teeth was recorded in the clinical examination and on orthopantomographs.

Complementary examinations
In the adult subjects, complementary clinical examinations were performed in order to elucidate etiological factors to caries.

Motoric ability
Finger force was measured in Studies I and II by letting the subjects squeeze a force transducer using a "key-grip", according to the method described by Helkimo *et al*. (1975).

In Study II, oral muscular coordination ability was measured according to the method described by Landt (1983). Two pairs of test pieces round and square and consisting of two parts, matrix and patrix, were assembled by letting the patient manipulate them in the mouth. The mean time of three trials for each pair was recorded. A maximum time of three minutes was set.

Salivary secretion
In Study II, stimulated salivary flow was measured by collecting whole saliva after chewing paraffin for 5 minutes and expressed as ml/min

Salivary glucose clearance
In Study II, oral sugar clearance time was estimated after the intake of a glucose containing tablet and expressed as the time (in minutes) required for the salivary glucose concentration to drop to 5 mmol/l (Hase *et al*., 1987). This level was chosen because it corresponds to 0.1% as suggested by Swenander Lanke (1957). The individual clearance time was calculated according to the mathematical formula described by Swenander Lanke (1957). The initial salivary glucose concentration was defined as the glucose concentration (mmol/l) found one minute after tablet ingestion. The area under the curve (AUC) for the salivary glucose concentration was calculated by a computer (Caleida-Graph, Abelbeck Software, PA, USA).

Dental Care
Data on dental care was retrieved from questionnaires and observation charts.

Statistical methods
Student's t-test was used to evaluate differences between groups in all studies. Data was also analyzed with the Mann-Whitney test in some cases and approximately the same significances were found. Occasionally, means and differences were given with a 95% confidence interval.

For categorical data, the X^2-test and Fisher's exact tests were used to assess differences between the groups.

Anova, completed with Student-Newman-Keuls multiple test, was used for comparing the four groups in Study IV.

Correlations were measured by means of Spearman´s and Pearson's correlation coefficients. In Study II, a multiple regression model was used.

In all the studies, $P<0.05$ was considered statistically significant. Multiple inference aspects were taken into account by not over interpreting single weak significances.

Comments on subjects and methods

The unique opportunity to be part of two large multiprofessional studies of patients with DM made the studies in this thesis possible. It would not otherwise have been feasible to gather so many patients with well defined diagnosis of this rare disease. The DM groups are small and heterogeneous in age but, because of the low prevalence of the disease, must still be considered a large number of patients examined.

In all the studies, consideration had to be taken to the fact that the patients easily tired. Still, they volunteered to participate in the studies with an impressive willingness and enthusiasm.

Subjects
In the two studies of adult persons with DM, the original 27 patients constituted the vast majority of persons with the diagnosis in the vicinity of Gothenburg. The diagnosis was based on clinical signs as the method with DNA analysis of blood samples was not known at that time. Therefore, it is possible that some of the DM patients did not have the DM type 1 diagnosis. The results of the examinations may have been influenced in various ways depending on the traits of possible other diagnoses. This applies to all studies of DM before 1992 when molecular diagnosis was made possible.

The children in the two last studies were 88 % (56 out of 64) of the known cases in the western and southern part of Sweden. The remaining 12 % did not wish to participate in the study for various reasons. They were all diagnosed by DNA analysis of blood samples.
The controls were matched as to age and gender.

Methods

Questionnaires

The questionnaires are well tried out and tested. The Mun-H-Center questionnaire and observation chart have been in use since 1996 for examinations of patients with rare disorders. Data is entered into the database at the Mun-H-Center which is a Swedish national orofacial center of expertise and a national resource center for orofacial aids and appliances for the disabled.

However, in all cases for adult DM patients and in some for the children with DM1, the questionnaires were answered by persons with classical DM who might have cognitive deficits affecting their ability to answer questions.

Mouth breathing

Information on mouth breathing was gathered from the questionnaires and clinical observations only. More reliable methods for recording this exist, e.g. rhinomanometry (Giuca et al., 2009), but they may have proved too tiring for the DM1 patients and were therefore not deemed necessary.

Radiographs

Some of the children with DM1 could only tolerate extra-oral radiographs, which are not so adequate for caries diagnosis. On account of the difficulty found in the DM1 group to cooperate, the quality of the radiographs taken was not always optimal. Both these facts rendered a more uncertain caries diagnosis.

Clinical examination

All methods in the clinical examination protocol are well-known methods used in standard examinations. Examination methods that are not so tiring were chosen since DM patients often are easily fatigued and have difficulties keeping their mouths open.

Oral hygiene

A simplified Silness-Löe index of oral hygiene on four teeth was used in the study of the adult patients. The index indicated very poor oral hygiene in the adult DM patients. Therefore, it was decided to register visible plaque index (VPI) and gingival bleeding index (GBI) on all surfaces in the children. Some of the children with DM1 could not cooperate well during the examination, leading to a probable under-reporting of plaque, gingivitis and caries.

Finger force

Finger force was used in the adult studies as an indicator of general muscle strength and it was measured according to a method described by Helkimo et al. (1975). Maximal finger force was recorded between the index finger and thumb, applied on an apparatus consisting of two occluding forks provided with strain gauges. In 1978, Helkimo et al. recorded the maximal force between the thumb and index finger on the right and left hands of healthy male dental students. The results of right and left hand were pooled to obtain an expression of the general muscle strength. It seems that this method is still a valid one to evaluate muscular strength and is still used in many studies, e.g. by Kiliaridis *et al*. (1993), Guimaraes *et al*. (2007), and

Botteron *et al*. (2009). In our studies, we wanted a comparison of the mean muscular strength in the DM group and the control group. We also used this method to study correlations of the finger force to other variables.

Oral muscular coordination ability

The oral muscular coordination ability was tested according to the method (MA test) described by Landt in 1983. He used four different test pairs to fit together in the mouth. Three groups were tested; children, young adults and elderly adults. Young adults used the shortest time and elderly the longest, with the children in between. He also used 12 different test pieces to identify in the mouth against patterns in what he called oral recognition of forms (RF) test. With this he tested oral stereognosis or oral perception. The time it took for identification and the number of incorrect identifications were recorded. The same groups of test persons were used and the results were similar to the MA test. It was originally intended to be used to evaluate a patient's ability to adapt to removable dentures. The MA test has since been used with slight alterations in many studies e.g. Hase *et al*. (1987); Crossner *et al*. (1991); Alstad *et al*. (2008). In these studies, the intention has been to evaluate the ability to coordinate the movements of the lips and tongue in order to eliminate food particles, which has a great influence on oral clearance. Similar tests have also been used to evaluate the stereognostic ability in persons with speech difficulties (Speirs & Maktabi, 1990). A positive correlation between oral stereognostic ability and masticatory ability has been shown by Hirano *et al*. (2004).

Salivary secretion

Stimulated salivary secretion was measured in the adult patients in Study II. Ideally, the test should not be performed within 90 minutes after a meal, but in this study it was not always feasible. Unstimulated salivary flow was not measured since it was considered more tiresome and time consuming for the patient. According to a mathematical model, one of the most important factors affecting oral sugar clearance is unstimulated salivary flow (Dawes, 1983). However, the flow rate of stimulated and unstimulated saliva has been found to be highly correlated (Österberg, 1981; Heintze *et al*., 1983).

Oral sugar clearance

The methods to calculate oral sugar clearance may vary as to what sugary liquid or solid substance is used and how the saliva samples are collected. In the adult patients in Study II it was calculated according to the method described by Hase *et al*. (1987). The same method has been used in numerous studies e.g. Hase & Birkhed, 1988; Hase *et al*. (1991; 1992), Crossner *et al*. (1991), Lundgren *et al*. (1997), Alstad *et al*. (2008). Another method, involving spitting through funnels into test tubes at determined intervals after rinsing with 20% sucrose solution, was used by Lagerlöf *et al*. (1994). The method used by Hase *et al*. is not demanding on the patient. Therefore, it is suitable for patients easily fatigued or patients with other difficulties cooperating, such as DM patients. However, it is time consuming and was, therefore, not used in the studies of the children with DM1 since they have more difficulties than the adult patients cooperating during dental treatment.

Results

Oral hygiene

Adults: The mean number of tooth brushing occasions per day was 1.7 in the DM group and 2.1 in the control group in Study II. Fluoride toothpaste was used by all participants. Extra fluoride or other prophylactic measures were used sporadically in the DM group and more frequently in the control group. In both study groups, the plaque index had significantly poorer values in the DM group than in the control group (Table V). In Study I, molars had more plaque than incisors in both groups.

	DM group		Control group		
Study	Mean	Sem	Mean	Sem	p-value
Study I Silness-Löe 8 surfaces	1.13	0.09	0.24	0.04	<0.0001
	Mean	SD	Mean	SD	p-value
Study II Silness-Löe 8 surfaces	1.3	0.5	0.2	0.2	<0.001
Study III VPI % all surfaces	35.9	37.9	3.9	4.2	<0.0000
Study III VPI % bucc surfaces	49.5	9.7	8.6	9.7	<0.0000
Study IV:1 VPI % all surfaces	36.0	38.9	3.7	3.4	<0.0000
Study IV:2 VPI % all surfaces	53.7	35.6	7.3	6.8	<0.0000
Study IV:1 VPI % bucc surfaces	51.5	39.5	9.3	9.0	<0.0000
Study IV:2 VPI % bucc surfaces	69.1	38.7	16.4	20.3	<0.0000

Table V. Mean and standard error of the mean (Sem) / standard deviation (SD) in plaque indices from adult studies (I and II), cross-sectional (III) and longitudinal (IV) studies in DM and control groups. P-values denote significance levels for differences between the groups.

Children: All the children participating in the cross-sectional study brushed their teeth daily. Twenty-three in the DM1 group and 15 in the control group were helped with tooth brushing. Fluoride, beside F-containing toothpaste, was used by nine of the DM1 patients and 10 in the control group. Thirteen of the DM children and six of the control children used some kind of other hygienic aid, e.g. an electric toothbrush.

In the longitudinal study, oral hygiene habits did not change in any remarkable way between examinations. According to the questionnaires, the vast majority of children in both groups brushed their teeth twice a day. Twenty-five subjects in the DM1 group and five in the control group were still helped with their tooth brushing at Examination 2. All persons in both groups used fluoride containing toothpaste and the use of other fluoride products was 2-3 times more frequent in the DM1 group than in the control group. The difference in use of fluoride was significant at Examination 2 ($p = 0.019$). Devices to improve oral health, such as

electric toothbrushes, were more frequent in the DM1 group (p = 0.048 at Examination 1 and p = 0.003 at Examination 2).

The VPI values were higher in the DM group in the cross-sectional study and this was more evident in VPI on buccal surfaces (p<0.0000). The differences were even more evident in the older age groups where the boys, in particular, showed abundant plaque. The results were similar in the longitudinal study and the increase of VPI between examinations was larger in the DM1 group (Table V).

In the longitudinal study, when the groups were split according to gender for ages up to ten years and over, the differences as to visible plaque on the buccal surfaces were statistically significant for all groups except girls under ten.

Periodontal disease

Adults: Gingival pockets in the molar region differed significantly between the groups. In the incisor region, the difference was not significant in Study I (Table VI). No differences were found between the groups regarding the alveolar bone height, measured as the distance between the alveolar bone crest and the cemento-enamel junction.

Differences between DM and Control group

	Study I					Study II				
	DM(n=27)		Control (n=27)			DM (n=17		Control (n=17)		
Variable	mean	Sem	mean	Sem	p-value	mean	SD	mean	SD	p-value
Dietary score						46.8	25.2	26.2	17.7	<0.01
Number of teeth	20.7	1.79	23.6	1.01	<0.05	24.5	3.5	24.6	4.8	ns
DMFT	22.5	0.77	21.3	0.98	ns	22.9	3.5	18.6	4.7	<0.01
DMFS						67.4	16.0	53.2	22.2	<0.05
DMFSa in pre-molars, molars	26.3	1.13	21.1	1.39	<0.01					
DFSa in pre-molars, molars	14.9	1.76	14.5	1.44	ns	21.3	6.0	14.7	6.0	<0.01
DFSa % in pre-molars, molars	72.9	4.30	56.8	4.60	<0.02					
Ging. pockets incisors	0.4	0.13	0.2	0.11	ns					
Ging. pockets molars	1.7	0.27	0.9	0.19	<0.02					
Ging. pockets molars, incisors						2.8	2.5	0.6	0.9	<0.01
Pontics, number	0.1	0.08	1.5	0.69	<0.05					
Finger force (N)	31.4	2.55	84.4	4.61	<0.001	17.3	8.4	68.6	32.8	<0.001

Tabell VI. Mean values and Sem / SD of dietary score, number of teeth, caries indices (DMFT, DMFS and, in premolars and molars, DMFSa, DFSa and DFSa %), Gingival pocket > 4mm in incisors and molars, number of pontics and finger force in DM patients and controls in Studies I and II

Children: GBI values were higher in the DM group than in the control group in the cross-sectional study (p<0.001). The difference was even more evident in the older age groups,

especially among the boys. The results were similar in the longitudinal study and the increase between examinations was larger in the DM1 group (Fig. 3).

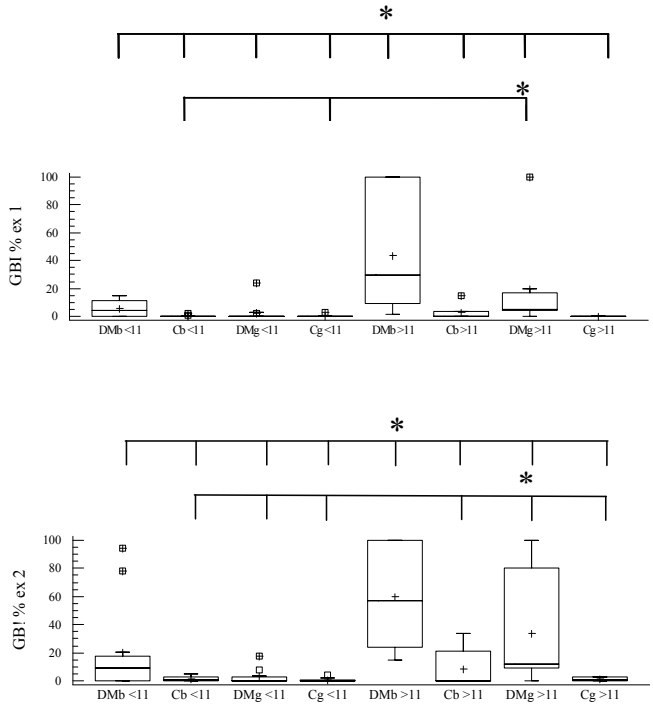

Figure 3. Gingival bleeding in Examination 1 and 2 in longitudinal study of children with DM. DMb = boys with DM, DMg = girls with DM, Cb = control boys, Cg = control girls. The groups are divided into children under and over 11 years of age at Examination 1. Boys with DM over 11 years of age have a significantly higher GBI value than all other groups in both examinations. In Examination 1, girls with DM over 11 years of age have a significantly higher GBI value than control boys and control girls under 11 years of age while in Examination 2, girls with DM over 11 years of age have a significantly higher GBI value than all control boys and girls, as well as DM girls under 11 years of age.

Caries and restorations

Adult: In Study I, DFSa, as a percentage of the number of remaining proximal surfaces, showed a higher affected number in the DM group than in the control group ($p<0.02$). DMFSa values were also higher ($p<0.01$) in the DM group than in the control group, while DMFT values did not differ significantly. In Study II, DMFT, DMFS and DFSa values were higher in the DM group (Table VI). The groups are not based on the same individuals, therefore, the figures cannot be compared longitudinally. There is a statistically significant difference as to DMFT and DFSa in Study II, but not in Study I.

Children: In the cross-sectional study, all caries indices for permanent teeth were higher in the DM1 group than in the control group, except for the number of decayed surfaces (DS). In the primary dentition, there was more initial caries on buccal surfaces in the DM1 group than in the control group (Fig 4). In the comparison of the 20 percent of participants with most caries in both groups, the difference was even more evident. All indices except decayed permanent surfaces (DS) were higher in the DM1 group (Fig 5). When stratifying the groups according to gender, the differences were larger for boys, especially in the older ages.

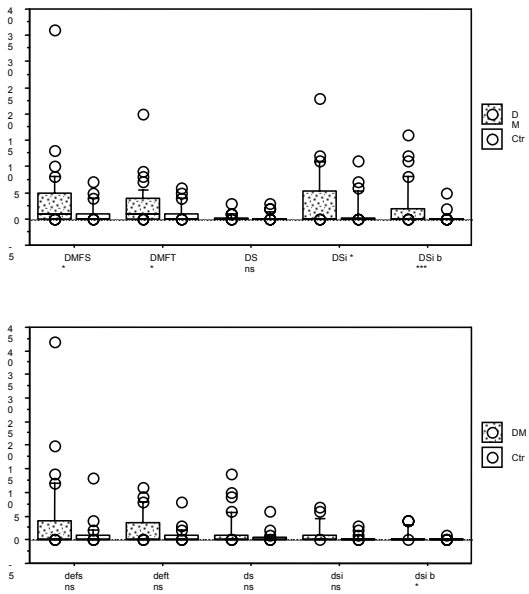

Figure 4. Box plot of caries indices (DMFS, DMFT, DS, DSi, DSi buccal, defs, deft, ds, dsi and dsi buccal) in the DM1 and control group. Each box plot is composed of five horizontal lines that display the 10th, 25th, 50th, 75th and 90th percentiles of a variable. All values for the variable above the 90th percentile and below the 10th percentile are plotted separately. (*= $p<0.05$, **= $p<0.01$, ***= $p<0.001$, ns= not significant)

Significant correlations between the number of CTG-repeats and caries indices were found for deft ($r=0.35$, $p= 0.04$) and ds ($r=0.34$, $p=0.04$) and between the subgroup of DM1 and caries indices for defs ($r= -0.35$, $p=0.04$) and deft ($r=-0.37$, $p=0.03$). When testing the correlations in the different subgroups of DM1, a negative correlation was found between CTG-repeats and DMFT ($r=-0.7$, $p = 0.04$) and DMFS ($r= -0.77$, $p=0.02$) in the severe congenital group.

Children with DM1 in the longitudinal study had more caries than the children in the control group. There was a statistically significant difference between the groups in DMFS and DMFT at both examinations and in the increase between the examinations (Table VII). In the first permanent molars, DMFS was higher in DM1 patients at both examinations and in DSib only at the second examination (Table VII). All other increases in indices between examinations during the study period were also larger for the DM1 group than for the control group, although they did not reach statistically significant levels. The increase of defs and

DMFS in molars in the two groups split for gender is presented in Figure 6. Boys stand for the major part of the increase in caries in the DM1 group (DMFS, p = 0.003).

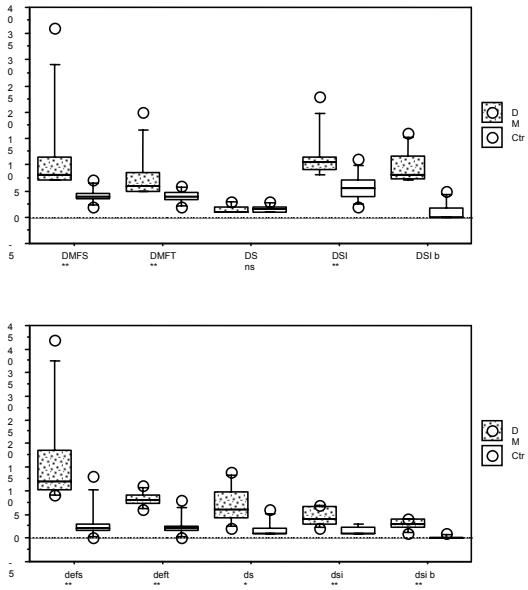

Figure 5. Box plot of caries indices (DMFS, DMFT, DS, DSi, DSi buccal, defs, deft, ds, dsi and dsi buccal) for the 20 percent with most caries in the DM1 and control group. Each box plot is composed of five horizontal lines that display the 10th, 25th, 50th, 75th and 90th percentiles of a variable. All values for the variable above the 90th percentile and below the 10th percentile are plotted separately. (*= p<0.05, **= p<0.01, ***= p<0.001, ns= not significant).

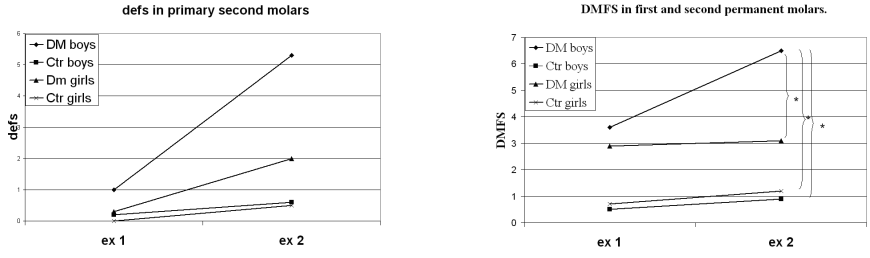

Figure 6. Changes split for group and gender in decayed, extracted and filled surfaces (defs) in second primary molars and decayed, missing and filled surfaces (DMFS) in first and second permanent molars between Examinations 1 and 2. * denotes significant differences between groups (p<0.05).

The patients in the DM1 group had a significantly larger increase in manifest and initial caries on the buccal and lingual smooth surfaces of permanent molars (Fig. 7). Manifest caries in incisors was found in one DM1 patient at Examination 1 and three at Examination 2.

	DM1			Ctr			
Variable	n	mean	SD	n	mean	SD	p-value
DMFS all permanent teeth							
Examination 1	31	3.9	6.9	29	0.6	1.5	0.014
Examination 2	36	5.4	9.8	33	1.0	1.7	0.012
Differences between examinations	31	2.5	4.8	29	0.5	0.8	0.028
DMFT all permanent teeth							
Examination 1	31	2.6	4.2	29	0.6	1.4	0.012
Examination 2	36	3.3	4.9	33	0.9	1.6	0.008
Differences between examinations	31	1.2	1.9	29	0.4	0.7	0.047
DMFS in first permanent molars present at both examinations							
Examination 1	29	2.4	3.0	27	0.3	0.8	0.001
Examination 2	29	3.5	4.0	27	0.7	1.1	0.001
Differences between examinations	29	1.1	2.2	27	0.4	0.8	0.125
DMFS b in first permanent molars present at both examinations							
Examination 1	29	0.2	0.6	27	0.0	0.0	0.142
Examination 2	29	0.4	0.9	27	0.0	0.0	0.051
Differences between examinations	29	0.2	0.5	27	0.0	0.0	0.061
DSi b in first permanent molars present at both examinations							
Examination 1	29	0.5	1.1	27	0.1	0.5	0.126
Examination 2	29	0.6	1.2	27	0.0	0.0	0.017
Differences between examinations	29	0.1	1.2	27	-0.1	0.4	0.555

Table VII. Mean value and SD for caries indices at Examination 1 and 2 and the differences between them in the longitudinal study. P-values denote significance levels for differences between the groups.

Number of teeth

Adults: The number of teeth differed significantly in Study I but not in Study II (Table VI). Four patients in the DM group in Study I, but none in the control group, were edentulous.

The number of pontics was significantly higher in the control group than in the DM group in Study I, (1.53 sem 0.69 versus 0.11, sem 0.08, $p<0.05$).

Children: Four patients in the DM1 group had in total seven permanent molars extracted due to caries. In the control group, no patient had permanent molars extracted due to caries.

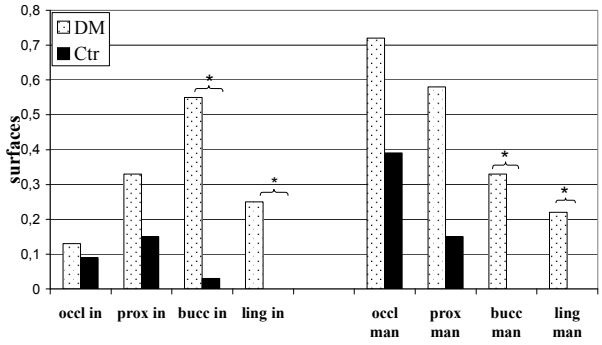

Figure 7. Increase in caries on different surfaces in permanent molars between Examinations 1 and 2 in DM1 and the control group. Occl = occlusal, prox = proximal, bucc = buccal, ling = lingual, init = initial caries, manif = manifest caries. * denotes significant difference between the groups ($p < 0.05$).

Etiological factors

Motoric ability

Adults: In both studies, the mean finger force expressed as N was much lower in the DM patients than in the control patients (Table VI). A strong correlation was found between finger force and the oral hygiene index ($r = 0.62$, $p<0.0001$). The mean values of oral muscular coordination ability (MA-test) were less favorable in the DM group than in the control group (Table VIII). The differences were statistically significant for all these variables.

Variabel	DM		Control		p-value
	mean	SD	mean	SD	
Salivary factors					
-Secretion rate	1.0	0.6	1.8	0.6	<0.01
Oral sugar clearance factors					
-Initial concentration	114.0	104.9	50.4	34.0	<0.05
-Clearance time (min)	12.3	5.6	7.5	3.0	<0.01
-AUC (mmol x min)	419.3	343.3	165.0	117.2	<0.01
Motoric ability factors					
-MA-test: round	56.3	63.1	13.4	9.2	<0.01
-MA-test: square	67.5	62.3	25.1	22.5	<0.05

Table VIII. Mean values and standard deviation (SD) of salivary, oral clearance and motoric ability factors in DM and control patients in Study II. P-values denote significance levels for differences between the groups.

Salivary factors
Adults: The salivary secretion rate was lower in the DM group than in the control group (Table VIII).

Oral sugar clearance
Adults: The mean salivary glucose concentrations were higher in the DM group than in the control group at all time points. There were significant differences between the two groups for initial glucose concentration, clearance time and AUC ($p<0.01$) (Fig. 8; Table VIII).

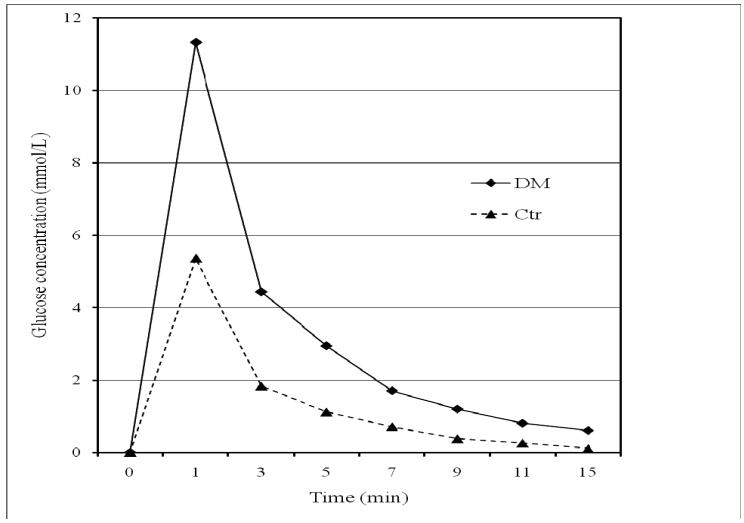

Figure 8. Mean salivary glucose concentration after chewing a glucose tablet in the DM group (n = 17) and the control group (n = 17).

Mouth breathing and dry mouth complaints
Adults: All of the DM patients and two control patients reported breathing through their mouths while sleeping. Fourteen of the DM patients and four in the control group also complained of dry mouths.

Children: Mouth breathing was common in the DM1 group where 50 out of 56 slept with their mouths open compared to nine out of 56 in the control group in the cross-sectional study. In the longitudinal study, 31 reported sleeping with their mouths open at Examination 1 and 32 at Examination 2, compared to four in the control group at both examinations ($p= 0.000$ at both examinations).

Dietary score
Adults: In Study II, there was a statistically significant difference in the dietary score for cariogenic products between the two groups ($p<0.01$), largely due to the frequent intake of sweet beverages between meals in the DM group. Twelve DM patients reported this compared to four in the control group.

Children: The dietary score in the cross-sectional study did not differ between the groups; DM1 group score 26 and control group score 25. In the longitudinal study, the dietary score

did not show any significant difference between the groups during the follow-up period either; DM1 group 26.9 at Examination 1, 27.8 at Examination 2, control group 26.5 at Examination 1, 24.2 at Examination 2. The reported time for meals was longer for the children with DM1 (Ex 1: p=0.001, Ex 2: p=0.005) and they chewed gum only sporadically (Ex 1: p=0.037, Ex 2: p=0.002) compared to the healthy controls.

Dental care

Adults: The average number of visits to a dentist per year was 1.6 in the DM group and 1.2 in the control group. The number of visits to a dental hygienist per year was on average 1.8 in the DM group and 0.4 in the control group.

Children: In the cross-sectional study, the number of visits to a dental clinic was higher for the DM1 group, mean 3.1, sd 1.0, than for the control group mean 1.1, sd 0.1 ($p<0.001$). Thirty-two of the DM1 children were treated by pedodontists and in 19 cases, also by a general practitioner. Thirteen DM1 children had orthodontic care and 25 used oral screens or other devices for orofacial training. Eight of the control children had received orthodontic care. All patients in both groups were satisfied with the dental care they received.

Among the DM1 patients, general anesthesia was needed in 17 of 56 cases. In 14 further cases, it was estimated that it would be needed if more extensive treatment was to be carried out. None in the control group needed general anesthesia. The examiner's estimation of cooperation ability (on a scale from 1 to 10) showed more difficulties in the DM1 group than in the control group. The corresponding estimations by the patients/parents were also higher in the DM1 group (Table IX). There were significant correlations between CTG-repeats and the estimation of cooperation ability made by both the examiner ($r = 0.52$, $p = 0.0001$) and the patients/parents ($r = 0.44$, $p = 0.001$).

Variable	n	DM1 mean	SD	n	Ctr mean	SD	p-value
BMP Ex 1	31	3.9	3.2	33	0.2	0.5	0.000
Coop Ex 1	32	3.9	3.5	30	0.8	1.6	0.000
BMP Ex 2	35	3.7	3.1	33	0.2	0.3	0.000
Coop Ex 2	35	3.9	3.2	30	0.9	1.1	0.000

Table IX. Behavior management problems and patient cooperation problems on a scale from 0 = no problems to 10 = major problems. Dentist's and patient's/parents' estimation at Examination 1 and 2. (BMP = behavior management problems, dentist's estimation; Coop = patient cooperation problems, patient's/parents' estimation; p-values concern the differences between the groups)

According to questionnaires in the longitudinal study, the frequency of visits to dental clinics was higher in the DM1 group than in the control group at both examinations; 3.3 ± 3.8 compared to 1.1 ± 0.3, ($p = 0.002$) at Examination 1, 2.8 ± 1.6 compared to 1.2 ± 0.6, ($p = 0.000$) at Examination 2. Pedodontic and/or orthodontic specialist care was more common among the DM1 patients than the control patients; 16 compared to three at Examination 1 ($p =$

0.001) and 21 compared to two at Examination 2 ($p = 0.000$). The estimation of behavior management problems did not change much between the examinations and the DM1 group had more problems than the control group (Table IX). The correlation between estimations at Examinations 1 and 2 was $r = 0.79$, $p = 0.000$ for examiner, and $r = 0.49$, $p = 0.000$ for patient/parents. The need for general anesthesia, carried out or deemed necessary at more extensive treatment, increased somewhat in the DM1 group between examinations; 18 at Examination 1 and 20 at Examination 2. There was no need for general anesthesia in the control group.

Discussion

Congenital DM1 and DM1 with childhood onset are severely disabling diseases. The classical type of DM1 is a slowly progressing but in time disabling disease, while the mild type with onset late in life and slight symptoms gives few problems. The DM patients participating in the examinations presented in this thesis all have either the congenital, childhood onset or classical type of DM. The four studies summarized in this thesis all point in the same direction, that persons with the inherited disease DM1 have poorer conditions for good oral health than control persons of the same age and gender. This concerns most aspects of oral health. In DM1, many traits that may influence oral health are present: Poorer motoric ability, possible hyposalivation, learning disability, anxiety and other neuropsychiatric problems and moreover, for children, the fact that one of the parents always is affected by the classical type of the disease. This thesis deals primarily with the two major oral diseases: Periodontal disease and caries.

Oral hygiene

The most striking finding in both the adult patients and the children with DM1, above all in the boys, is the large amount of plaque and gingivitis found. This is especially the case on buccal surfaces. That plaque removal may be difficult for persons with muscular weakness has been shown in numerous studies (Morinushi, 1986; Matsson & Bäckman, 2001; Symons, 2002; Marton, 2005; Guimaraes, 2007). In Study I of this thesis, a correlation between finger force and plaque index was shown and the patients with DM had difficulties in maintaining good oral hygiene, especially in the posterior region. The progressive character of muscle wasting in DM1 could be an explanation for the increased amount of plaque, gingivitis and caries in the children with DM1 as they grow older, as shown in Studies III and IV. This was most evident in the male group, especially the adolescents. In healthy children there is, on the contrary, an age related increase in motoric skills and the ability to brush teeth (Sundell & Klein, 1982). Patients with these difficulties in maintaining good oral hygiene often need the help of a carer. This is obvious for the very young children but also in the adolescents with the more serious types of DM1. Adult persons with classical DM1 grow progressively weaker and in time also often need the help of a carer. The DM1 patients with less impairment and more independent living may be at greater risk for poor oral hygiene as they grow older, than those with more daily care needs. Patients with learning disabilities and/or neuropsychiatric problems, who have been moved from institutions to more independent living, have large amounts of plaque and unmet dental needs (Gabre, 2000; Persson, 2009). According to Waldman & Perlman (2000), 80% of the residents with disabilities in community living needed assistance in maintaining their oral hygiene, but only half of the care providers had received any oral hygiene instructions during the past year. In addition, for young DM1 patients living at home, one of the parents is afflicted by the same disease and has a lesser ability to help with oral hygiene measures. This leaves an even greater burden for the other parent. Therefore, the need for instructions in how to achieve and maintain good oral hygienic conditions for the patient and/or carer is very important, but often overlooked. The adults with DM in Studies I and II had somewhat poorer oral hygiene habits than the control group. On the contrary, the children with DM1 in Studies III and IV had somewhat better habits according to questionnaires. This may show that during the years that have passed between the studies, information on the importance of tooth brushing and fluoride toothpaste and other prophylactic measures has spread. Still, even more information and care are evidently needed.

Periodontal disease

There were clear differences as to signs of gingival inflammation between the DM1 patients and the control patients in all four studies. This is in accordance with the findings in studies

on other diseases entailing muscular weakness (Mattsson *et al*., 2001; Symons *et al*., 2002; Marton *et al*., 2005) Similar findings have also been reported in studies from persons with learning disabilities and/or neuropsychiatric disorders (Gabre, 2000; Persson, 2009). Mouth breathing or incompetent lip closure is also associated with gingivitis (Matsson, 2001). Therefore, the fact that the majority of the DM1 patients were mouth breathers may also have contributed to the gingivitis found in them. In spite of the frequency of plaque and gingivitis found, the adults with DM had the same alveolar bone level around the remaining teeth as the control group. This is a further confirmation of the predominant view that periodontal disease does not necessarily correlate to supragingival plaque levels (Papapanou, 1988).

Gingivitis is reversible if etiological factors are eliminated but if left untreated, may lead to more serious forms of periodontal disease (Mariotti, 1999). Long-standing gingivitis in children may be indicative of an underlying disease and should be investigated (Sjödin & Matsson, 2009). Poor oral hygiene and gingivitis may also constitute a risk for infective endocarditis due to the bacteremia during tooth brushing (Lockhart *et al*., 2009). The possibility that periodontal disease may be associated with systemic diseases, such as coronary heart disease, has been proposed. Periodontal disease is also a threat to persons with a chronic disease, such as diabetes (Seymour *et al*., 2007). These facts emphasize the necessity for information on oral hygiene habits and help with professional prophylactic care. This is especially important for DM1 patients who are not only burdened with progressively weaker muscles, but also, especially in those with congenital and childhood onset types may have learning disabilities and/or neuropsychiatirc disorders.

Caries

More caries was seen in adult patients and children with DM1 compared to healthy controls in all four studies in this thesis. In children with DM1, an analysis of caries prevalence and incidence on different types of surfaces showed a significantly larger increase in both manifest and initial caries on the buccal and lingual smooth surfaces of permanent molars. This is indicative of a high caries activity since these surfaces usually are the least decayed when caries prevalence falls (McDonald & Sheiham, 1992; Batchelor & Sheiham, 2004).

In Papers III and IV, it was shown that the difference in caries prevalence appeared at an early age, especially in boys. Males having more caries than females have, has been shown in some studies (Crossner & Unell, 2007; Migale *et al*., 2009). However, according to the Swedish National Board of Health and Welfare (2006), there is no difference in caries prevalence between boys and girls in Sweden. The majority of the children with the severe congenital form of DM1 in this study were boys. Severity of DM1, however, did not always coincide with high caries prevalence, which often affected the older boys with the less serious types more. An explanation for this could be that the children most seriously affected by DM1 are the ones least able to manage by themselves. They receive more care and could thus be less seriously affected by lifestyle diseases such as caries. This is in accordance with studies on oral health in mentally retarded adults, which have shown that individuals with mild mental retardation, living with their family or in their own apartments, show a higher caries incidence and prevalence compared to subjects with severe mental retardation living in institutions (Gabre, 2000).

The decrease in caries prevalence in the industrialized part of the world has brought a skewness of the distribution, as there still is a small but constant group of patients with a high number of carious teeth (Slåttelid Skeie *et al*., 2009). It is probable that many of the patients with DM1 and similar disabling diseases are found in this latter group.

Number of teeth

The number of occluding teeth is of great importance for bite force, the ability to chew (Tsuga *et al*., 1998; Österberg, 2002; Alstad, 2008; Brennan, 2008; Ueno, 2008) and salivation (Jensen Kjeilen *et al*., 1987; Yeh *et al*., 2000; Ikebe *et al*., 2007). The adult DM patients had fewer remaining teeth, fewer pontics and there were more cases of total edentulism in this group than in the control group. Thus, there seemed to be a certain difference in choice of therapy between the groups. Similar findings regarding the choice of therapy for groups of handicapped have previously been reported e.g. by Siegal (1985) and Gotowka *et al*. (1982). Since there was no difference as to the alveolar bone height between the groups, one might assume that caries, and not periodontal disease, was the main reason for tooth loss in the DM group. They also grew up in a period with less oral hygiene prophylactic treatment, more extensive amalgam therapy and very little prophylactic use of fluoride. In the studies by Gabre *et al*. (2000; 2001) on oral health in mentally retarded adults, more teeth were lost due to periodontitis, but more individuals had lost teeth due to caries. A large number of the patients in her studies had Downs's syndrome, where severe periodontitis is a greater problem, possibly due to the altered immune response resulting from the underlying genetic disorder (Morgan, 2007). In normal Swedish populations, caries is the main reason for tooth mortality in persons under the age of 50 years (Eckerbom *et al*., 1993).

The children with DM1 had molars extracted due to caries compared to the control children who did not. Since the DM1 patients generally had more caries and on surfaces that nowadays mostly are caries-free in the population, and moreover had difficulties cooperating during dental treatment, they often received their dental care under general anesthesia. The therapy chosen then often was extraction in cases where survival of the tooth was in doubt. Similar findings are reported for children with disabilities from other countries. Pradhan *et al*. (2009) reported that persons with disabilities requiring general anesthesia for routine dental treatment had a higher prevalence of missing teeth. Oral screening of the Special Olympics Athletes (persons with mental retardation ages eight and over) show high levels of tooth loss, soft tissue infections and periodontal disease (Shenkin *et al*., 2001).

Etiological factors

In order to try to explain why patients with DM had higher caries prevalence, different factors believed to be related to the caries process were examined, e.g. oral hygiene index, dietary index, oral sugar clearance, salivary secretion and oral muscular coordination ability. A larger proportion of these aggravating etiological caries-related factors were also shown in the DM patients; more plaque, slower oral glucose clearance, lower stimulated salivary flow decreased and decreased motoric ability.

Plaque and diet

Plaque is a prerequisite for the carious process but does not necessarily lead to caries. The acid producing bacteria in plaque also need fermentable carbohydrates. In Paper II in this thesis, a difference as to dietary habit was shown. This especially concerned sweet beverage that were consumed in a higher degree in the DM group than in the control group, possibly due to the DM patients' complaint about a frequent feeling of dry mouth. Mouth breathing may lead to a feeling of dry mouth (Dawes, 2004) and habitual mouth breathing was common in the DM group. It is well-known that consumption of sugar between meals increases the risk of dental caries (Lundquist, 1952; Gustafsson *et al*., 1954) and this may be accentuated in individuals with dry mouth (Hase & Birkhed, 1988, Lingström & Birkhed, 1993). The difference between DM patients and the controls in *dietary habits* could not be verified in the Papers III and IV on oral health in children. Since a decade has passed between the examination in Papers II and III, possibly the knowledge about the benefits of choosing a

healthy diet to avoid caries has been further spread and influenced the answers in the questionnaires.

Motoric ability

It is generally agreed that decreased muscular strength leads to difficulties in maintaining good oral hygiene and an increased risk for caries and gingivitis (Morinushi, 1986; Matsson & Bäckman, 2001; Symons, 2002; Marton, 2005; Guimaraes, 2007). Significantly lower finger force was recorded in Studies I and II. The poor oral hygiene shown in the DM patients in Study I was strongly correlated to their weakened motoric ability as demonstrated by their lower finger force value. A positive correlation between handgrip force and bite force has been shown, among others, by Gumaraes *et al*., (2007) and they concluded that weakness of the masticatory and hand muscles may have various negative consequences for oral function and dental health in patients with myotonic dystrophy.

Reduced muscle strength and motoric function in the group of children with DM1 compared with control children was reported by Kroksmark *et al*., (2005). According to Sjögreen *et al.* (2007), a majority of these children with DM1 had a moderate or severe impairment of lip motility, tongue motility and lip force. Oral motoric dysfunction was most prominent in congenital DM1 and males were more affected than females. As discussed earlier, this could be an explanation for the larger amounts of plaque and gingivitis found in the male DM1 patients. The progressive character of muscle wasting in DM1 could explain the increased amounts as the children grew older.

Sensory function is important for initiating the muscular actions in self-cleaning. "*For normal sensormotor abilities, i.e. the interaction between sensory impressions and motor function, intact structures and function are demanded…*". For most people, this is something taken for granted. For persons with oral motoric disturbances, it is of utmost importance that their difficulties are mapped (Edebol Eeg-Olofsson, 2001). The strong correlation between muscular coordination on the one hand and self-cleaning ability and oral clearance on the other has been shown by numerous studies (Swenander Lanke, 1957; Hase, 1993; Alstad 2008). The method of assessing oral muscular coordination ability used in Study II, both showed that this ability was less pronounced in DM patients. Hase examined oral muscular coordination ability in elderly by using the MA-test and found longer assembly time for the test pieces indicating lower coordination ability. He concluded that this may depend on age related alterations in the mouth. The elderly may not perceive the long retention time of the sugar containing products in the mouth, and if they do, it is possible that they are not able to make the required movements in order to eliminate the products properly from the oral cavity (Hase, 1987). The same line of argument may be conducted for patients with myotonic dystrophy and other diseases leading to weakness in the orofacial muscles.

Saliva

The adult DM patients in Study II had lower stimulated salivary secretion than the control persons. Unstimulated flow rate was not measured. According to a mathematical model, one of the most important factors affecting oral sugar clearance is unstimulated salivary flow (Dawes 1983). However, the flow rate of stimulated and unstimulated saliva has been found to be highly correlated (Österberg, 1981; Heintze *et al*., 1983).

The role of saliva is manifold. It lubricates, buffers, helps in creating a reparative environment and contains antibacterial proteins and digestive enzymes. Hyposalivation prolongs oral clearance and increases caries and gingivitis. Saliva secretion is partly controlled by the masticatory-salivary reflex with impulses from chewing activated mechanoreceptors in the periodontal ligament (Bardow *et al*., 2004). Jensen Kjeilen *et al*.

(1987) showed that mechanoreceptors have a major role in the parotid response to chewing and that salivation increased with the increase in frequency and force of chewing and with the number of teeth in occlusion involved. This is in accordance with later studies, e.g. Yeh *et al*. (2000) and Ikebe *et al*. (2007). The adult DM patients in Study II and in other studies (Willig *et al*., 1994; Pennarocha et al., 1990) and the children with DM1 in Studies III and IV (Sjögreen *et al*., 2007; 2008) reported difficulties in swallowing. This leads to avoidance of food that is hard to chew and a preference of products that do not need chewing. This could also, on a long term basis, affect the salivary factors negatively and thereby increase the risk of dental caries. The low stimulated salivary flow rate found in the DM group in Study II thus might partly be due to impaired mastication (Ödman & Kiliaridis, 1996).

Salivary secretion was not measured in the children in Studies III and IV in other ways than observation of signs of dry mouth or drooling at the clinical examination. One third of the patients had problems with drooling. In a few it improved but in others saliva control deteriorated over the years as a sign of disease progression (Sjögreen *et al*., 2008). Search of literature does not give evidence of dry mouth in young people with myotonic dystrophy, so possibly this is a trait that becomes more of a problem as the patient grows older.

Oral clearance

Oral clearance is the process of eliminating a substance from the oral cavity. It is influenced by many traits and is an individual property as shown in the Vipeholm study (Swenandner Lanke, 1957) and other studies, e.g., Lagerlöf *et al*. (1994). In small children, the oral clearance is slower than in adolescents and adults but improves with the increasing age of the child (Crossner *et al*., 1991). In the caries process, it is the elimination of sugar which matters. Prolonged salivary sugar concentration affects the acid production in dental plaque and thereby increases the caries risk (Lundquist, 1952; Risheim *et al*., 1992). A factor which tends to accelerate sugar elimination from saliva is a high frequency of chewing movements before the food is swallowed (Swenander Lanke, 1957; Hase *et al*., 1987). Swenander Lanke also found a marked influence on the course of elimination by the movements of the lips and tongue after the substance had been swallowed. This has been further corroborated by Hase (1993) who reported a correlation between salivary glucose clearance and oral muscular coordination ability. Oral sugar clearance has also been found to correlate to the incidence of caries (Lundquist, 1952; Ericsson *et al*., 1954; Lundgren, 1997; Hase *et al*., 1987). Slow oral clearance and an increased risk of dental caries in persons with oral motoric dysfunction has also been shown by Gabre *et al.* (2005). Alstad *et al*. (2008) found that the strongest predictor of dental caries in the elderly was oral sugar clearance and this in turn was related to chewing efficiency and motoric ability. A long time for the oral motoric ability test was associated with slower clearance. They concluded that "*oral function may be both an effect of dental caries, due to tooth losses and a cause of it, due primarily to the effect of oral clearance*" (Alstad *et al*. 2008).

Thus, one important explanation for the high caries prevalence in the DM patients may be their relatively slow oral clearance as shown in Study II. Many of the influencing traits are found in them such as poorer motoric ability and low salivary secretion.

Learning disability and neuropsychiatric problems in persons with DM1

The shown differences between persons with DM1 and control persons as to plaque, gingivitis, dental caries and number of teeth, and the etiological factors oral clearance and salivary secretion, are all more or less influenced by their decreased motoric ability. In addition to this, children with DM1 often have learning disabilities and neuropsychiatric problems (Harper, 2001; de Die Smulders, 2000; Ekström *et al*., 2008; 2009) that lead to

problems in many aspects of daily living, e.g. dental care as shown in the cross-sectional and longitudinal studies. The question whether adult persons with the classical type of DM1 also have these problems is debated (Tuikka *et al*., 1993; Palmer *et al*., 1994; Winblad. 2006). However, socio-economic consequences such as a lower educational level and a higher degree of unemployment have been shown (Veillette *et al*., 1986; Perron *et al*., 1989; Fowler *et al*., 1997; Laberge *et al*., 2007). Excessive daytime sleepiness is a common complaint in DM1 patients (Ekström, 2009). Adult patients with DM1 also score high in the personality traits harm avoidance and fatigability (Winblad, 2006). A high anxiety score also has been shown (Antonini *et al*., 2006). It appears that the CNS-related symptoms, such as cognitive deficits, daytime sleepiness and neuropsychiatric symptoms, cause more problems in daily life for persons with DM1 than the neuromuscular symptoms (Ekström, 2009).

Impact of DM1 on oral hygiene program and dental care

The mental problems of the disease often necessitate some kind of sedation in order to carry through reparative treatment or the extraction of decayed teeth. The disease entails an increased risk in connection with sedation and general anesthesia (Mathieu *et al*., 1997; Harper, 2001). Therefore, it is even more important for this group of patients to avoid accumulation of treatment needs.

A difference in choice of therapy from the dental profession for persons with DM1 is seen. In Study I, it was shown that more extractions and less prosthetic therapy were carried out in the DM patients. It must be remembered that the studies of adult DM patients were performed around 20 years ago and the dental care registered had been done prior to that. In studies of dental care for persons with mental retardation Gabre *et al*. (1999) found that the ability to cooperate with dental treatment is an important factor in reducing the incidence of tooth mortality. Individuals with severely reduced cooperation had higher scores of dental plaque, more severe gingivitis and had lost more teeth compared to those subjects who cooperated better. A low level of cooperation ability in many of the DM1 patients was demonstrated in the studies of children with DM1 and did not improve with older age in the longitudinal examination. In persons attending psychiatric outpatient services, it was found that dental status, expressed as numbers of missing teeth, was higher than in the general population (Persson *et al*., 2009). In many countries, the large institutions for people with mental retardation have been shut down and the patients moved out to various kinds of more independent living in the community. There are numerous reports on greater unmet oral health needs in these patients than in those still living in institutions with organized dental care (Gabre, 1997; Waldman & Perlman, 2000; Tiller, 2001; Stanfield, 2003, Persson, 2009). Awareness of the importance of oral health care to the well-being of their clients needs to be raised among municipal health personnel (Hagman-Gustafsson *et al.* 2008).

As has been shown, DM1 may lead to social situations resulting in lack of economic resources to be able to pay for optimal dental care and also sometimes a lack of interest in getting the care. Therefore, it is important for patients with DM1 and other disabilities to have a dental insurance model that makes it possible to afford the often costly dental treatments. In Sweden, legislation from 1999 is intended to guarantee disabled persons who receive supportive care from the community, free oral health assessment at home. The county council also has to subsidize the subsequent dental care for costs exceeding the cost of ordinary medical care (National Board for Health and Welfare, 1998). For children and adolescents dental care is free of charge up to the age of 20. Thus, in Sweden, the economic conditions of dental care for people with disabilities have improved.

Taking into consideration the reported difficulties in swallowing (Pennarocha *et al*., 1990; Willig *et al*., 1994), confirmed by the adults with DM in Study II and the children with DM1

(Sjögreen *et al*., 2007), it seems even more important for DM 1 patients to have a good dental status so as not to further impair their chewing ability and, on a long term basis, affect the salivary factors negatively due to poor dental conditions.

"*Since carious lesions form as a result of the metabolic events in the dental plaque, plaque control must be the cornerstone of preventive non-operative treatment*" (Kidd *et al*., 2008). As shown, the DM patients in these studies had high plaque indices, however, with individual variation. In the questionnaires, the adult DM patients reported almost as good oral hygiene habits as the control group. The children with DM1 reported as good or better habits as the control group and they visited dental clinics more often than the control children. Still, their oral health was not as good as that of the control patients. Even more intensive prophylactic care seems to be needed and non-operative treatment ought to be the first choice of therapy for these patients.

Since DM1 is not a curable disease today, persons suffering from it in varying degrees according to the severity of the disease, will be dependent on assistance from carers or the dental profession for their oral hygiene care. For the younger patients, frequent visits to the dental clinic for professional cleaning are advantageous both for caries and gingivitis prophylaxis and getting the patient accustomed to the dental clinic and treatment there. Cooperation between the public dental clinic close to where the patient lives, for prophylactic care with short intervals, and the specialist dental clinic for treatment planning and specialist care, ought to be optimal for the DM1 patients. The studies by Axelson & Lindhe showed that professional cleaning at frequent intervals can bring down the caries incidence to almost zero (Axelsson, 2006). It is particularly efficient on surfaces that are difficult to clean such as proximal surfaces and is justified in persons with high caries activity (Nyvad, 2008).

Home care methods for plaque removal and fluoride treatment, that are easy to manage, are also desired. Instructions in methods for plaque removal and information on tools that are useful both for the patient and carer are essential. Special toothbrushes with sets of bristles arranged to brush buccal, lingual and occlusal surfaces simultaneously or battery operated toothbrushes may be helpful when the muscular strength and coordination ability are reduced and are also often easier for a carer to use. Cheek retractors facilitate inspection of the teeth and control of the result of cleaning. Chemical plaque control, e.g. chlorhexidine gel or solution, is a useful adjunct in many cases. For fluoride prophylaxis, fluoride toothpaste is the base and other fluoride vehicles, such as gels, rinses and tablets can be added when necessary. Attempts have been made with a slow release F-paste to be applied by nursing staff in the night. It is a promising vehicle for caries prevention in subjects unable to follow traditional home care (Gabre *et al*., 2005; 2008). Stimulation of saliva through the chewing of fluoridated sugar free chewing gum has proven positive (Jenkins & Edgar, 1989; Ly *et al*., 2008) but may be too tiresome for persons with DM1. Dietary advice is important and should stress the importance of avoiding sugar containing drinks and snacks in between meals.

In cooperation with speech therapists, training programs may be instituted in the children with DM1 to try to improve the oral muscular ability. An example of this is training with lip shields to improve lip strength and lip closure.

Seamless care for persons with disabilities

In the care of persons with disabilities, it has been pointed out that cooperation between the different professions involved is very important. This has been confirmed by the researchers participating in the examination of the children with DM1 in this study. One of the benefits of the cooperation is a better understanding of the disease. A holistic approach to patient care is of great value. Similar thoughts have been expressed by numerous authors. According to the

British Society for Disability and Oral Health, the concept of *seamless care* refers to continuity of healthcare received by a patient across the spectrum of caregivers and their environments. The aim of the oral healthcare provision for adults with disabilities and additional needs is to provide a seamless approach to care as they move through the age groups (Lewis *et al*., 2008). The omission of oral health issues from the medical agenda implies a risk of oral health problems in children with disabilities (Hallberg & Klingberg, 2005). Therefore, it is essential that the dental team initiates cooperation with the medical care system or vice versa. This is also emphasized by Persson (2009), who dealt with the correlation between oral health and quality of life, the individual consequences of interaction between dental and psychiatric services and the societal impact oral health has on the individual. One of her conclusions is that questions concerning oral health and dental attendance should be addressed regularly, both in the psychiatric care services as well as in other medical and social services.

Today, multidisciplinary orofacial treatment teams are common in many counties in Sweden. However, it is important that all personnel encountering these patients should be able to carry out a basic evaluation of orofacial functions (Bakke *et al*., 2007). Multiprofessional guidelines, including an oral healthcare program for patients with DM1 in the Nordic countries, have recently been compiled (Dystrofia myotonika Skandinaviskt koncensusprogram 2008) and are available on the internet (www.orebroll.se). Furthermore, dental educational programs need to be developed to enable dental personnel to assist persons with disabilities (Shenkin *et al*., 2001; Hallberg *et al*., 2004).

Conclusions

- Adult persons with the classical type of DM have a somewhat higher caries frequency compared with healthy control persons.
- They have more plaque and gingivitis and lower finger force than healthy control persons. The finger force is correlated to the oral hygiene index.
- They seem to have the same alveolar bone support around remaining teeth as healthy control persons, even if they have more plaque and gingivitis.
- They have longer oral sugar clearance time, lower salivary secretion rate, higher frequency of intake of sugar containing products and a lower oral motoric ability than healthy control persons.
- Children with DM1, especially the older boys, have more plaque, gingivitis and caries than healthy peers. Behavior management problems are frequent in the dental situation correlated to the severity of the disease.
- In children with DM1, the disease results in a more pronounced deterioration of oral health, over time, compared to control patients. The DM1 patients show increasing amounts of plaque and are at a continuous and increasing risk of caries and gingivitis. Behavior management problems are common and do not seem to decrease with age.
- Children and adult persons with DM1 should be regarded as risk patients for dental caries and gingivitis, according to the severity of their progressive muscle disease, and should be given individual prophylactic advice and care.

Acknowledgements

I would like to express my gratitude to everyone who has helped me during the years that the work with this thesis has been going on. I especially wish to thank:

- My supervisors, Professor Stavros Kiliaridis, Professor Dowen Birkhed, associate Professor Agneta Robertson and Odont. Dr. Sten Sundell, who have helped and guided me with such encouragement and patience.

- Professor Mar Tulinius and the members of the multidisciplinary research group, especially my companion Lotta Sjögreen, in the examinations of the children with DM1.

- All the participating persons in the DM and control groups and their families who made the studies possible.

-Sven and the rest of my dear family who have had such patience with me.

To all you others, none mentioned and none forgotten, who have helped and inspired me in so many ways during all the years that this work has been going on: Thank you all!

Research grants were received from the Public Dental Service in Gothenburg, the Swedish Dental society, The Gothenburg Dental society, Sigge Persson's and Alice Nyberg's Foundation, the Institute of Odontology at the Sahlgrenska Academy, Göteborg, the Health and Medical Care Executive Board of the Region of Västra Götaland and Muskelfonden – Insamlingsstiftelsen Forskningsfonden för Neuromuskulära sjukdomar.

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