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Dental care in dogs

A survey of Swedish dog owners, veterinarians and veterinary nurses

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Cover: Dog with toothbrush
(photo: Peter Rutherhagen)

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Abstract

Dental problems are often encountered in dogs, with periodontal disease as the most common disease by far. Today, daily tooth brushing is the gold standard for dental home care in dogs. The aim of this study was to investigate attitudes and practices regarding canine dental care. Questionnaires were developed, validated and distributed to all registered Swedish dog owners, veterinarians and veterinary nurses. Responses were received from 66,434 dog owners (32%), 1,161 veterinarians (32%) and 624 veterinary nurses (38%).

Results showed that only 4% of dog owners brushed their dog's teeth daily. Another finding was the lack of early preventative dental home care information communicated by veterinary health practitioners to dog owners. Although dog owners perceived their pet's dental health as being of major importance (80%), many also reported difficulties when inspecting their dog's mouth (25%). Many owners (26%) reported having attempted to brush, but discontinued. It was more common for smaller dogs and for breeds known to be at risk of periodontal disease to have their teeth brushed. We propose that dog owners would benefit from extra support from e.g. veterinary practitioners to maintain dental home care routines for their dog.

Contrary to national and international guidelines, professional dental cleaning in veterinary clinics using sedation only, and dental extractions without access to dental radiography equipment, occurred commonly, highlighting room for improvement.

In conclusion, this thesis presents the attitudes, opinions and routines of Swedish dog owners, veterinarians and veterinary nurses regarding dental care in dogs, providing a basis for future improved prophylactic strategies.

Keywords: Dental home care; tooth brushing; canine; dental health; periodontal disease; breed; questionnaire; attitudes; opinions; routines.

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Tandvård hos hund. En undersökning bland svenska hundägare, veterinärer och djursjukskötare

Sammanfattning

Parodontal sjukdom är hundens vanligaste sjukdom och andra tandproblem är också vanligt förekommande. Daglig tandborstning är s.k. gold standard för hemtandvård hos hund liksom hos människa. Syftet med denna studie var att kartlägga attityder och rutiner avseende hundtandvård.

Enkäter utvecklades, validerades och distribuerades till samtliga registrerade hundägare, veterinärer samt djursjukskötare i Sverige. Enkätsvar mottogs av 66434 hundägare (32%), 1161 veterinärer (32%) och 624 djursjukskötare (38%).

Studien visade att endast 4 % av hundägarna borstade sin hunds tänder dagligen. Dessutom sågs en brist på tidig, preventiv information om hemtandvård, från veterinärer/djursjukskötare till hundägare. Hundägare ansåg att hundens tandhälsa var mycket viktig (80%), men många (25%) rapporterade också svårigheter vid inspektion av hundens mun. Många hundägare hade försökt borsta hundens tänder men upphört med detta (26%). Små hundar samt raser med ökad risk för dålig tandhälsa fick oftare sina tänder borstade. Resultaten visar att hundägare behöver ökat stöd från veterinärer/djursjukskötare för att upprätthålla hundens hemtandvård.

Tvärtemot nationella och internationella riktlinjer utfördes professionell tandrengöring ofta i sedering och tandextraktioner utfördes utan tillgång till dentalröntgen, vilket visar på förbättringspotential i klinikernas rutiner.

Genom ökad kunskap om svenska hundägares, veterinärers och djursjukskötares attityder, åsikter och rutiner avseende hundtandvård utgör denna avhandling en grund för att utarbeta förbättrade strategier för profylaktisk tandvård hos hund.

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Dedication

To my family

The more you know, the less you understand

Lao Zi

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Enlund KB, Brunius C, Hanson J, Hagman R, Höglund OV, Gustås P, Pettersson A. Development and validation of two questionnaires: Dental home care and dental health in Swedish dogs. PLoS One. 2019;14(1).

II. Enlund KB, Brunius C, Hanson J, Hagman R, Höglund OV, Gustås P, Pettersson A. Dental home care in dogs - a questionnaire study among Swedish dog owners, veterinarians and veterinary nurses. BMC Vet Res. 2020;16(1), p. 90.

III. Enlund KB, Brunius C, Hanson J, Hagman R, Höglund OV, Gustås P, Pettersson A. Dog Owners' Perspectives on Canine Dental Health—A Questionnaire Study in Sweden. Frontiers in Veterinary Science. 2020;7(298).

IV. Enlund KB, Karlsson M, Brunius C, Hagman R, Höglund OV, Gustås P, Hanson J, Pettersson A. Professional dental cleaning in dogs - Clinical routines among Swedish veterinarians and veterinary nurses. Acta Vet Scand. 2020;62(1), pp. 1-10.

Abbreviations

AAHA	American Animal Hospital Association
AVDC	American Veterinary Dental College
CFA	Confirmatory factor analysis
EFA	Exploratory factor analysis
EVDC	European Veterinary Dental College
WSAVA	World Small Animal Veterinary Association

1. Background

1.1 Historical aspects of periodontal disease and tooth brushing

Periodontal disease, also called gum disease, is common in many mammals, including humans and dogs. Archeological findings show that bone destruction caused by periodontal disease occurred even in prehistoric and ancient times, e.g. in a 3 million year old hominid and in human remains from ancient Egypt (Forshaw 2009). Dentists and dental hygienists worldwide have long worked actively to prevent and treat periodontal disease. Since 1938, the Swedish Public Dental Care (Folktandvården) has informed and educated children as well as the general population about the importance of dental home care for good dental health (Folktandvården 2021). Today, 85% of the population brush their own teeth at least twice a day (Norderyd *et al.* 2015b). This has resulted in markedly improved dental health, both regarding periodontal health and caries (Norderyd *et al.* 2015a). Even so, approximately half of all adults aged 30 or older still suffer from periodontitis, the more severe form of periodontal disease (Eke *et al.* 2012).

Tooth brushing has long been used to promote oral health. Early forms of toothbrushes existed as early as 3500 BC, in the form of "chew-sticks", a twig with a frayed end that was rubbed against the teeth (Zhou *et al.* 2013). In fact, in some cultures chew-sticks are still used for dental cleaning (Albabtain *et al.* 2018). Bristle toothbrushes dating from around 1600 BC, made from hogs' bristles, have been found in China. In the 1800s, bristle toothbrushes with carved handles and hog or horse bristles were in general use in Europe, and the first nylon bristle toothbrushes were introduced in the 1930s (Zhou *et al.* 2013).

Although periodontal disease may be even more common in dogs than in humans (Stella *et al.* 2018), a vast majority of dog owners do not brush their pet's teeth. The veterinary community thus has much to learn from human dentistry in order to increase tooth brushing and thereby promote dental health in dogs.

1.2   Dental disease in dogs

Dental disease is one of the most common health problems in dogs. Periodontal disease is the most common dental affliction, with a prevalence of at least 80% in dogs over 3 years (Hamp *et al.* 1984; Wiggs & Lobprise 1997; Kortegaard *et al.* 2008; Fernandes *et al.* 2012; Niemiec 2012; Stella *et al.* 2018). Periodontal disease is characterised by an inflammation of the soft and hard structures supporting the teeth, and, if untreated, may cause tooth loss (Reiter & Gracis 2018). Tooth fractures are also frequently detected, with a prevalence of around 26% (Soukup *et al.* 2015). Fractures with pulp exposure can be very painful and require treatment. Malocclusions are also very common, with a reported prevalence of 26-30% (Aula 2018; Hoyer & Rawlinson 2019). Afflicting the deciduous teeth and/or the permanent occlusion, malocclusion may cause severe problems that need treatment. Other dental problems include e.g. persistent deciduous teeth, gingival hyperplasia, avulsions or subluxated teeth, or tooth malformation and developmental disorders (Reiter & Gracis 2018). Dental caries, on the other hand, is extremely rare in dogs as opposed to in humans (Kyllar & Witter 2005). Regular visits to the veterinary practitioner, together with proper dental home care, constitute the basis for detecting dental problems and maintaining good oral health throughout the dog's life.

In 2018, the World Small Animal Veterinary association (WSAVA) published Global dental guidelines (WSAVA 2018). In addition, the American Animal Hospital association (AAHA) recently updated their guidelines regarding veterinary dentistry in dogs and cats (Bellows *et al.* 2019). These guidelines serve as recommendations and give instructions for the general veterinary practitioner in recognising and treating dental disease in dogs and cats.

Treatment of many dental diseases requires special training, and for veterinarians working within veterinary dentistry there are several possibilities for continued education and specialisation, ranging from day-

long courses in extraction techniques to board-certified specialist training programmes offered by the European and American Veterinary Dental College (EVDC and AVDC, respectively). In Sweden, a postgraduate three-year training programme in small animal dentistry results in the official title "Specialist in odontology in dogs and cats" (known as a Stage 2 specialist). Veterinary dentistry is one of the younger veterinary specialisations, with AVDC starting in 1988 and EVDC in 1998.

1.2.1 Periodontal disease

Periodontal disease is an inflammatory disease that affects the tooth's supportive tissue (periodontium), i.e. gingiva, periodontal ligament, cementum and alveolar bone (Wiggs & Lobprise 1997; Reiter & Gracis 2018). Periodontal disease includes two conditions: gingivitis, where the inflammation is confined to the gingiva, and periodontitis, where the inflammation also involves the rest of the periodontium leading to loss of attachment (Reiter & Gracis 2018).

Inflammation is initiated by dental plaque, a biofilm composed mainly of bacteria, salivary proteins and glycoproteins, which constantly covers the tooth surface in the absence of daily tooth brushing (Marsh & Bradshaw 1995). Dental plaque in the gingival sulcus initiates an immune response and the release of biochemical mediators, chiefly cytokines, prostaglandins and matrix metalloproteinases, which are largely responsible for the progressive tissue destruction seen in periodontitis (Fig. 1) (Meyle & Chapple 2015; Gehrig *et al.* 2018).

Dental plaque is soft and colourless, but when calcium salts and other minerals from the saliva are deposited, it hardens and forms dental calculus. Dental calculus in itself is not pathological, but it facilitates the adhesion of new dental plaque (Akcali & Lang 2018; Reiter & Gracis 2018).

The pathophysiology of periodontal disease is considered very similar in dogs and humans, and the dog has long been used as a model animal for periodontal disease in humans (Lindhe *et al.* 1973; Lindhe *et al.* 1975; Hamp *et al.* 1984; Corba *et al.* 1986a; Corba *et al.* 1986b; Tromp *et al.* 1986a; Albuquerque *et al.* 2012). However, although interspecies similarities have been shown (Yamasaki *et al.* 2012; Gołyńska *et al.* 2017), new studies have revealed that oral microbial taxa differ between humans and dogs (Dewhirst *et al.* 2012; Yamasaki *et al.* 2012; Davis *et al.* 2013; Wallis *et al.* 2015). Much of the etiopathogenesis of periodontal disease is still unknown, with

new knowledge emerging continuously (Hajishengallis *et al.* 2020; Loos & Van Dyke 2020).
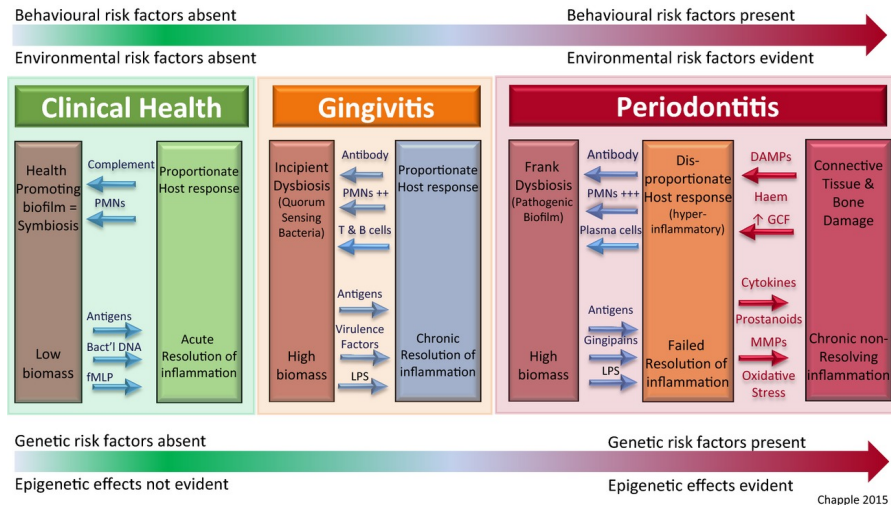
Figure 1. Model of pathogenesis of periodontal disease (Meyle & Chapple 2015). Reproduced with permission.

Gingivitis, the early st age of periodontal disease, is generally considered reversible with proper home care (Reiter & Gracis 2018). The symptoms are red and edematous, swollen gingiva that easily bleed on probing. The later stage of periodontal disease, periodontitis, is considered irreversible and entails the loss of supportive tissue, which, if untreated, results in the loss of the tooth. Symptoms at this stage may include retracted gingiva, root surface exposure, furcation exposure, tooth mobility and missing teeth (Fig. 2). Halitosis is common, as well as dental calculus (Reiter & Gracis 2018). However, periodontal disease may be extensive without any visible dental plaque or calculus, since subgingival plaque is enough to initiate and maintain inflammation. Symptoms often go unnoticed by the owner, since the dog often does not present obvious signs of discomfort (Fernandes *et al.* 2012). In fact, periodontal disease in humans is usually not accompanied with pain. This may contribute to delayed detection and treatment of the disease (Gaurilcikaite *et al.* 2017). Although a tentative diagnosis can sometimes be made based on clinical appearance in a non-anaesthetised animal, general anaesthesia is required for determining the full extent of periodontal disease (Bauer *et al.* 2018; WSAVA 2018).

Why gingivitis progresses to periodontitis in some individuals and not in others is not entirely understood (Van Dyke 2017). Plausibly, the individual immunological response in the dog may play a larger role than the specific species of bacteria that initiates the inflammation (Hajishengallis *et al.* 2020). Several predisposing factors for developing periodontitis have been identified, including behavioral risk factors (e.g. oral care, chewing habits), environmental factors (e.g. stress, nutrition) and genetic and epigenetic factors, including host response (Fig. 1) (Nares 2003; Meyle & Chapple 2015; Gonçalves-Anjo *et al.* 2019; Wallis & Holcombe 2020). Studies have also shown that small dogs and certain breeds of dogs are predisposed, and that the prevalence increases with age (Hamp *et al.* 1984; Harvey *et al.* 1994; Hoffmann & Gaengler 1996; Marshall *et al.* 2014; O'Neill *et al.* 2019; Wallis *et al.* 2019).

In humans, different forms of periodontal disease have been described (AAP 2015). Chronic periodontitis denotes the mostly slowly progressing form mainly found in adults. By contrast, aggressive periodontitis leads to rapid attachment loss, occurs mostly in younger and otherwise healthy individuals, and is often familial. In addition, both chronic and aggressive periodontitis may be differentiated into localised and generalised periodontitis (AAP 2015). No studies have investigated whether different forms of periodontitis exists in dogs (Wallis & Holcombe 2020).

Figure 2. Examples of periodontal disease (PD) stages according to AVDC. Left: Gingivitis (PD1). Also observed are dental fracture, abrasion and calculus. Photo Peter Rutherhagen. Right: Advanced periodontitis (PD4). Also observed are tooth loss, calculus and plaque. Copyright© AVDC®, used with permission.

The effect of diet on the development of periodontal disease has been a subject of much debate, and dietary texture does seem to have some effect

on the accumulation of plaque and calculus (Harvey *et al.* 1996; Gorrel 1998; Logan 2006). However, no diet has yet been shown to protect against periodontitis.

Local complications to periodontitis include e.g. oronasal fistula, perio-endo lesions and pathological fractures (Lopes *et al.* 2005; Niemiec 2012; Sauvé *et al.* 2019). Moreover, systemic effects of periodontal disease are of increasing concern in both humans and dogs. In humans, there is extensive evidence for associations between periodontal disease and e.g. cardiovascular disease, diabetes and adverse pregnancy outcomes (Kim & Amar 2006). In dogs, fewer studies have been conducted, and not all are in agreement (Peddle *et al.* 2009), but associations have been observed between periodontal disease and renal, hepatic and cardiac disease (Pavlica *et al.* 2008; Glickman *et al.* 2009; Glickman *et al.* 2011; Rawlinson *et al.* 2011; Semedo-Lemsaddek *et al.* 2016).

In humans, treatment of periodontal disease is provided by dental hygienists, dentists and specialised periodontists. Depending on the severity of disease, periodontal disease treatment may include scaling and root planing, or the use of a range of surgical procedures. So-called host-modulation therapy is also a possible treatment and subject to research (Elavarasu *et al.* 2012; Ipshita *et al.* 2017; Hajishengallis *et al.* 2020). In dogs, treatment is often confined to scaling, root planing and extraction of non-salvageable teeth. However, with the field of veterinary dentistry rapidly developing, more advanced surgical treatments are being offered, mainly by board-certified specialists. Nonetheless, surgical procedures for dental preservation are highly questionable if proper dental home care is not provided.

1.3   Dental home care

1.3.1   Active home care

Daily tooth brushing is the gold standard for maintaining periodontal health (Fig. 3) (WSAVA 2018). Tooth brushing may also prevent already existing disease from progressing. There is robust evidence that the removal of dental plaque through daily tooth brushing is effective in preventing gingival inflammation in both humans and dogs (Tromp *et al.* 1986a; Ingham & Gorrel 2001; Drisko 2013; Harvey *et al.* 2015; Sälzer *et al.* 2020). Although

there are multiple studies showing the effect of tooth brushing on the formation of dental plaque, calculus and gingival health (Deery *et al.* 2004; Buckley *et al.* 2011; Van der Weijden & Slot 2015; Allan *et al.* 2018), few studies concerning the efficacy of tooth brushing in dogs to prevent the development of periodontitis have been presented (Lindhe *et al.* 1975). Interestingly, randomised controlled trials regarding the clinical effect of oral hygiene on the prevention of periodontitis in humans are also lacking, and would in fact be considered unethical (Sälzer *et al.* 2020).

Brushing the teeth three times per week has been suggested as sufficient for maintaining dental health in dogs with clinically healthy gingiva (Tromp *et al.* 1986a). However, the beneficial effects of tooth brushing increase with frequency and brushing once daily is therefore recommended for all dogs (Lindhe *et al.* 1975; Corba *et al.* 1986a; Corba *et al.* 1986b; Tromp *et al.* 1986a; Tromp *et al.* 1986b; Harvey *et al.* 2015). Occasional brushing, on the other hand, has little or no effect, since bacterial colonisation of the plaque starts within hours after cleaning of the tooth surface (Li *et al.* 2004). In fact, mineralisation of dental plaque into dental calculus may start within only 2-3 days without brushing (Reiter & Gracis 2018). The effect of each tooth brushing session is thus short-term and the degree of gingivitis has in fact been shown to be the same in dogs after 4 weeks without brushing as in dogs that never receive tooth brushing (Ingham & Gorrel 2001). Furthermore, without brushing, bacterial species in the plaque are back to the levels found prior to dental cleaning within 5 weeks after dental prophylaxis (Flancman *et al.* 2018).

The mechanical removal of plaque along the gum line is key to success in preventing inflammation (Sälzer *et al.* 2020). Early implementation of tooth brushing is recommended in order to prevent future dental problems. The toothbrush should preferably be soft and of an appropriate size for the mouth. Toothpaste is of minor importance, but may be used to increase the dog's cooperation. Only toothpaste intended for dogs should be used to avoid excessive fluoride exposure. Training of the animal to accept brushing should ideally be gradual and include positive reinforcement (treats, praise) so as not to negatively affect the owner-animal bond (WSAVA 2018). However, even though brushing is the gold standard, only a minority of dog owners brush their dogs' teeth according to the recommendations (Ipsos 2016).

Figure 3. Daily tooth brushing is the gold standard for the prevention of periodontal disease. Photo: Peter Rutherhagen.

Textiles, e.g. gauze or microfibre, as an active means for cleaning dogs' teeth, are available on the market, indicating that some dog owners find this method easier to use compared to a toothbrush. Studies on the efficacy of using textiles for dental health promotion are scarce or absent in both humans and dogs, but the abrasive structure of textiles is thought to mechanically disrupt supragingival plaque by a rubbing action against the teeth. The cleaning ability of textiles overall and particularly in the dental sulcus and interproximal area between teeth is generally considered inferior to tooth brushing. However, it may be an acceptable solution if brushing is not a viable option (Eriksson & Kaj 2020).

Another means of active dental home care is the use of a chlorhexidine mouth rinse/gel, which has a safe and well-proven effect against plaque and gingivitis. However, there is a risk of antibiotic cross-resistance (Wand *et al.* 2017) and, furthermore, the therapeutic effect on periodontitis is likely to be low (da Costa *et al.* 2017; James *et al.* 2017).

1.3.2 Passive home care

A multitude of different feeds, chews, treats, supplements and additives are being marketed as promoting dental health in dogs. Few of these products have undergone controlled clinical trials and their use is thereby not evidence-based (Roudebush *et al.* 2005; WSAVA 2018). Some products have been proven to have some effect in clinical trials, where most provide a mechanical action in which the texture of the feed, treat or dental chew

scrubs off dental plaque during chewing (Jensen *et al.* 1995; Gorrel & Rawlings 1997; Gorrel & Bierer 1999; Hennet 2001; Logan *et al.* 2002; Brown *et al.* 2005; Hennet *et al.* 2006; Clarke *et al.* 2011; Quest 2013; Garanayak *et al.* 2019). The best effect on plaque removal is accordingly observed on premolars and molars (Roudebush *et al.* 2005; WSAVA 2018).

Manufacturers of veterinary dental health promoting products can submit research to the independent Veterinary Oral Health Council (VOHC) for evaluation of the scientific evidence of their product's efficacy (VOHC 2019). However, it should be noted that the effect assessed by VOHC relates to a decrease in plaque and/or calculus, while periodontal status is not assessed (WSAVA 2018). Products that aim e.g. to delay mineralisation of dental plaque, or just treat halitosis, may be assumed to have little effect on the development of periodontal disease.

Dog owners commonly provide their dog with natural chews (e.g. rawhide) or dental chews, either as pastime, as a reward and/or for promoting dental health (Morelli *et al.* 2020). However, the effect of natural chews on dental health has not been confirmed in controlled clinical trials, and published studies relate only to brand-specific products (Lage *et al.* 1990; Hennet 2001; Stookey 2009).

Many dog owners consider giving their dog a bone as a way to care for its dental health. However, chewing on marrowbones is often discouraged by veterinary practitioners due to the risk of tooth fractures. The role of chewing activity in the development of dental fractures is not entirely understood, and may depend not only on the hardness of the chew but also on the individual dog's eating pattern (Soltero-Rivera *et al.* 2019). Feeding bones is subject to many opinions among dog owners as well as veterinary practitioners, and the term "bones" may include a broad range of different skeletal components. Marrowbones, bought in pet stores, are often warm-dried or smoke-dried and are harder than "raw meaty bones", which may be anything from bovine femoral cortical bone to chicken necks. Chewing bones may have an overall positive impact on dogs' dental health (Marx *et al.* 2016; Pinto *et al.* 2020), but no large studies have been published and results should thus be interpreted with caution. In addition, one study showed that dogs being fed a "natural diet" did not have better dental health compared with other dogs (Robinson & Gorrel 1997). One large study concluded that chewing in itself was beneficial for dental health (Harvey *et*

al. 1996). However, since the study was cross-sectional, causality was not evident.

The idea that specific types of food can have a cleaning effect on teeth is not new, and has also been proposed in humans. However, a human intervention study, where subjects chewed carrots instead of brushing their teeth, showed no difference between chewing carrots and no oral hygiene at all (Lindhe & Wicén 1969), and the same has been shown to be true for the chewing of apples (Rubido *et al.* 2018).

Despite much research in the field of passive dental home care, daily tooth brushing remains, by far, the most effective way to reduce plaque accumulation and calculus formation (Allan *et al.* 2018). Veterinary dentists agree that passive home care may be seen as a complement to tooth brushing, but not a replacement (WSAVA 2018).

1.3.3 Adherence to dental home care

The World Health Organization (WHO) defines adherence as: "the extent to which a person's behaviour – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider" (WHO 2003). The term *compliance* is sometimes also used, but *adherence* is the term used more often today since this wording aims to place the clinician-client partnership/relationship more in focus, acknowledging the client's role to a greater extent.

In human medicine, adherence to recommended life-style changes is generally low. One literature review reports that 40% of patients failed to take prescribed medication correctly, or did not take them at all, and almost twice this number failed to adhere to recommended behavior changes such as dietary or exercise recommendations (Dimatteo *et al.* 2002).

Communication and communication skills have long been a field of research in human medical situations, and are also acknowledged as important factors for adherence in veterinary medicine (AAHA 2009; Gray & Moffett 2013; McArthur & Fitzgerald 2013; Bard *et al.* 2017). The way veterinary recommendations are provided is crucial for the client's motivation to implement the advice (Miller & Rollnick 2012). Educational efforts and reminders/follow-ups have been suggested as ways to improve adherence. However, good adherence to medical advice is difficult to achieve, even with complex interventions with multiple motivational components (Costa *et al.* 2015).

Only a few studies based on small study groups have addressed adherence to dental home care recommendations and tooth brushing in dogs (Miller & Harvey 1994; Bäcker *et al.* 2011), illustrating the need for more research in this area.

1.4   Professional dental cleaning and examination in dogs

State-of-the-art professional dental cleaning, according to the WSAVA, includes a complete oral assessment, supra- and subgingival scaling (ultrasonic and/or hand-scaling), polishing, dental radiographs and the formation of a treatment plan (WSAVA 2018).

1.4.1   Anaesthesia

Professional dental cleaning should be performed under general anaesthesia (Fig. 4). The dog should be intubated with an endotracheal tube and connected to a closed circle, thus enabling a thorough dental cleaning (subgingival as well as supragingival) and examination of the oral cavity, while minimising the risk of debris, aerosol or gastric content entering the airways (WSAVA 2018). However, dental cleanings are often performed under sedation only, which may lead to an increased risk of aspiration as well as an incomplete dental cleaning (WSAVA 2018).

Figure 4. Professional dental cleaning should be performed under general anaesthesia with the dog connected to a closed anaesthetic circle. Photo: Peter Rutherhagen.

So-called anaesthesia-free dentistry is strongly discouraged, since the risk of injuries to both dog and handler is imminent. In addition, since the removal of supragingival calculus does not protect against periodontal disease and must be seen as mainly cosmetic, dog owners may be lulled into a false sense of security (WSAVA 2018).

1.4.2   Professional dental cleaning

The goal of a professional dental cleaning is the removal of supra- and subgingival dental plaque and calculus. Treatment of pathologic periodontal pockets, i.e. depuration and root planing, is also part of the procedure. Usually, the cleaning is performed by ultrasonic scaling, preferably followed by hand-scaling. The teeth are then polished to remove any remnant plaque or unevenness and to leave a smooth surface (Reiter & Gracis 2018; WSAVA 2018).

The examination includes a thorough evaluation of the oral cavity and all individual teeth, noting any abnormalities. This is often easier to perform after the teeth have been cleaned, since dental calculus may otherwise obscure any pathologies. Periodontal health is examined with the help of a periodontal probe and any periodontal pockets are measured and noted (WSAVA 2018).

Full mouth radiographs are recommended as part of the examination. An absolute minimum entails radiography of any pathologic findings (WSAVA 2018). It is common for pathological conditions as well as anatomical deviations to be identified in radiographs (Verstraete *et al.* 1998). Radiography before and after performing tooth extractions is therefore mandatory to avoid complications (WSAVA 2018).

1.5   Survey methodology

To acquire valid results in a survey, sampling error, coverage error, measurement errors and non-response error must be evaluated (Dillman *et al.* 2014). Ignoring survey methodology when conducting a questionnaire survey risks obtaining data of a lower quality.

In order to avoid *sampling error*, the sample population (all those receiving a questionnaire) should be representative of the target population (all those we want to study) (Dillman *et al.* 2014).

To avoid *coverage error*, the respondents should be representative of the sample and target population. The actual sample population may differ from the intended one, i.e. some of the questionnaire recipients may not belong to the actual target group (over-coverage), and some people who belong to the target group may not receive a questionnaire for various reasons (under-coverage) (Dillman *et al.* 2014).

The number of respondents needed in a survey depends on problem definition. A larger sample is often more reliable, but not always. Respondent burden should be kept to a minimum, both because of ethical reasons and to ensure a high response rate (Berntson *et al.* 2016; Wenemark 2017). The statistical power of a study depends largely on the number of respondents, but inference is also affected by the representativity of the respondents to the target population (Berntson *et al.* 2016).

Measurement errors are common in questionnaire surveys and occur if the gathered data contains incomplete or inaccurate material, e.g. due to imperfect wording of questions or response scales (Marsden & Wright 2010).

Higher response rates lower the risk of *non-response error*. Low response rates may be caused by recipients not answering the questionnaire at all (external non-response) or skipping certain questions within the questionnaire (internal non-response). Internal non-response may be random or systematic, where systematic non-response generally poses a bigger problem. Much research has been conducted on strategies to increase questionnaire survey response rates, e.g. on the use of incentives, reminders, aesthetic layout, etc. (Edwards *et al.* 2009). However, the most important factor seems to be that respondents find the survey topic interesting (Edwards *et al.* 2002). Discrepancies between the respondents and the total population are common, which is why a non-response analysis is always recommended to determine the representativity of the respondents and their responses. As a minimum, a comparison regarding e.g. age and gender between respondents and the target population should be performed (Berntson *et al.* 2016).

1.5.1 Reliability and validity

The consistency of a questionnaire, i.e. its reliability (Fig. 5), is often assessed by test-retest, which assesses the stability (the repeatability) of item responses over time. A questionnaire item can be defined as an individual question with associated response options. Inter-rater agreement is another

way of measuring reliability, i.e. consistency between different assessors. Internal consistency, i.e. to what extent several items measure a single latent variable, is generally measured by Cronbach's alpha, which ranges from 0 (complete lack of internal consistency) to 1 (absolute internal consistency) (Cronbach 1951). Although Cronbach's alpha has received criticism as a measure of internal consistency (Sijtsma 2009), it is still a widely used metric.

Validity is the term used to describe whether a questionnaire actually measures what it is intended to measure (Fig. 5). *Content validity* is commonly assessed by subject-matter experts, often combined with cognitive interviews with representatives of the target population, to ensure that the test measures all facets of a given topic or concept. *Criterion validity* pertains to the relation of the measure to a pre-specified outcome (Ejlertsson 2005).
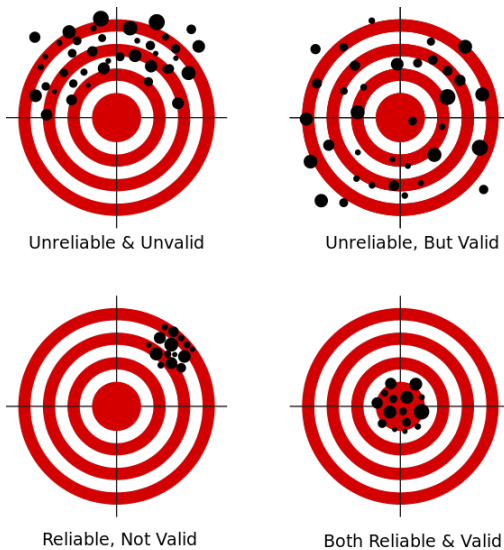

Figure 5. Reliability and validity. Attribution: © Nevit Dilmen, via Wikimedia Commons

Several items may be combined to form a "construct", in which an underlying theory or idea containing various conceptual elements is assembled (Berntson *et al.* 2016). *Construct validity* can thus be described as the extent to which the theoretical knowledge basis is in fact

operationalised (Ejlertsson 2005). The construct can be identified in the data e.g. through an exploratory factor analysis, and confirmed by a confirmatory factor analysis, and expert examination may confirm it as a construct for a certain underlying theory.

1.5.2 General guidelines in questionnaire construction

Basic guidelines to minimise measurement errors should be applied as far as possible when constructing a questionnaire (SCB 2004): Ensure that the order of the questions follows a logical sequence. Negations, difficult words, abbreviations and technical terms should be avoided as far as possible and technical terms should be defined and explained if they cannot be avoided. Neutral questions should be used to avoid acquiescence bias ("yea-saying"). Questions should be specific and reference dates/periods, when applicable, clearly stated and kept unchanged. Positions of answer boxes and directions within response alternatives should be unaltered between questions, for example going from seldom (left) to often (right) or bad (left) to good (right), and the same sort and number of response alternatives should be reused as far as possible. Clear and simple language should be used, using questions that are formulated accurately, clearly and with brevity to make it possible for the respondents to give a clear answer. The response options should be formulated to cover all conceivable options and to be mutually exclusive. Summarising questions (i.e. asking two questions in one) and abstractions should be avoided, and hypothetical questions used with care (SCB 2004).

Nominal, ordinal and interval scales may be used as response options, depending on the research question. Where the response alternatives are fixed statements, the order of the options may be randomised to each respondent in order to avoid answer order bias (priming) (Bradburn *et al.* 2004; Marsden & Wright 2010). Fixed response alternatives should also be carefully formulated to reduce the risk of influencing respondents. Vague quantifiers (e.g. "Sometimes", "Often", "Fairly") as response options should be interpreted with caution since these words have different meanings in different contexts and for different people, and therefore do not reflect actual frequencies (Cliff 1959; Tourangeau *et al.* 2000).

Studies have shown that the most reliable and valid response scales are of intermediate length, from 5-9 points/response options (Marsden & Wright 2010). Scales can have even or odd numbers, depending on whether a neutral or middle option is appropriate.

To manage respondent uncertainty, a "don't know" alternative may be used, although a possible disadvantage with "don't know" options can be that respondents use it without consideration. In fact, some data suggests that adding such an option does not improve measurement (Poe *et al.* 1988; Gilljam & Granberg 1993; Krosnick *et al.* 2002; Marsden & Wright 2010). However, without a "don't know" option, there is a risk of forcing the respondents to choose, even if they lack an opinion on the matter, which will lead to measurement errors (Marsden & Wright 2010).

Social desirability bias can also be problematic in some areas of research. To reduce this bias, judgmental formulations should be avoided and an explanation of the context may sometimes be added (Marsden & Wright 2010).

To conclude, at least a basic knowledge of the vast and extensive field of survey methodology is required to collect valid data when conducting a questionnaire survey.

2. Aims

The main aim was to investigate attitudes, opinions and practices regarding dental care in dogs, among dog owners, veterinarians and veterinary nurses, thereby providing a basis for improved prophylactic strategies.

Specific aims included:
- To develop and validate two separate web-based questionnaire surveys for this purpose.
- To investigate veterinarians' and veterinary nurses' information routines regarding canine dental home care.
- To investigate dog owners' perceived level of received information regarding dental home care from veterinary health practitioners.
- To chart dog owners' self-reported performance of dental home care for their dog.
- To investigate dog owners' assessment of their dog's dental health.
- To investigate self-reported professional dental cleaning routines in small animal practice in Sweden.
- To investigate associations between perceived dental health and dog breed, and associations between perceived dental health and specific chronic diseases.

3. Materials and methods

3.1 Study design

The study was designed as a mapping questionnaire survey with questions about attitudes, opinions and practices regarding dental care in dogs. Target groups consisted of all currently registered dog owners, all registered veterinarians and all registered licensed veterinary nurses in Sweden.

Sample frames were dog owners, veterinarians and licensed veterinary nurses with e-mail addresses registered with the Swedish Board of Agriculture (24 February 2017 for veterinarians and veterinary nurses; 13 March 2017 for dog owners). Veterinarians were also contacted by text message to their mobile telephone numbers from the same register. Furthermore, for dog owners, e-mail addresses registered with the Swedish Kennel Club (9 February 2017) were used.

The questionnaire surveys were adapted for use on personal computers, tablets and smartphones, using the web platform Netigate (Netigate AB, Stockholm, Sweden). The questionnaires were distributed and reminders were sent to non-responders after eight and seventeen days. Data collection started on 31 March and was completed on 30 April 2017. Anonymous responses were collected, and the questionnaire could only be answered once per link. If the household owned more than one dog, the respondent was instructed to choose one and answer for the same dog throughout the survey; 23% of the target population owned more than one dog (personal communication, Magnus Kindström, Swedish Board of Agriculture, 28 August 2017). The length of the questionnaire for individual respondents depended on their answers and ranged from 17 to 68 questions. The questions were mainly closed, i.e. with fixed response options, and both nominal and

ordinal data were collected. Details on survey administration are reported in Table 1.

Table 1. *Details of questionnaire recipients, responses and median response time.*

	Recipients	Total respondents	Complete responses*	Median response time
Veterinarians	3,657	1,161 (32%)	1,114	7 m 59 s
Veterinary nurses	1,650	624 (38%)	609	8 m 46 s
Dog owners	209,263	66,434 (32%)	59,978	10 m 17 s

* < 20% missingness among selected background questions

3.2 Construction and validation of questionnaires

Questionnaire items were initially formulated by the research team and were based on veterinary expertise within dentistry as well as a thorough review of the academic literature on periodontal disease and canine dental health.

Details of survey validation are described in Paper I and summarised in Fig. 6.

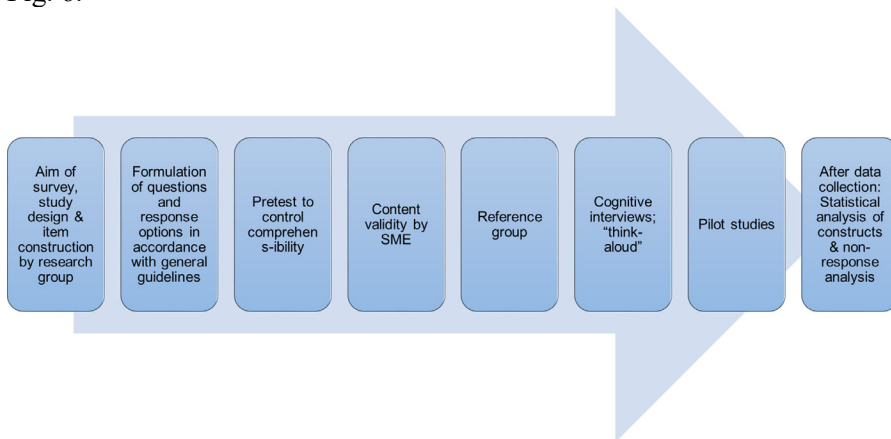*Figure 6.* Validation procedure (Paper I). SME denotes subject matter experts in odontology. Reference group consisted of representatives of target populations.

Items were adjusted and the questionnaires modified throughout the pre-defined validation process shown in Fig. 6.

Additional verification of face validity was conducted by examining 200 randomly sampled free text answers in the dog owner survey. In the

veterinary health practitioner questionnaire, all comments (n=169) were examined.

Several questions in the surveys were designed to reflect aspects of the same underlying concepts, namely opinions on canine dental home care and assessment of dental health. These *a priori*-defined constructs were thus designed to improve measurement accuracy through the use of multiple indicators (Berntson *et al.* 2016). For each construct, 5-6 separate questions likely to be associated with each such concept were identified. The questions were selected based on academic knowledge and clinical experience.

3.3   Data analysis

All statistical analysis was performed in the open-source statistical software R v 3.5.1 (36). All statistical analyses are described in detail in the publications.

3.3.1   Non-response analysis

To assess the representativity of the sample vs the target population (obtained from the Swedish Board of Agriculture registers), non-response analyses of gender, age, geographic and dog breed distributions were performed. Assessment of non-response is described in detail in Paper I.

3.3.2   Factor analysis

Prior to factor analysis, variables that were nominal, socio-demographic, had near zero variance, or responses only from a subpopulation due to logical conditions from previous questions, were removed (76 variables removed from dog owner data and 53 variables from the health practitioner data; Paper I). "I don't know" or "Other" responses were substituted with either a fixed or missing value on a per-variable basis (Paper I). Imputation of remaining missing values (3.9% in the dog owner data and 0.6% in the health practitioner data) was performed using an in-house Random Forest algorithm.

The data sets were randomly split in halves and exploratory factor analysis (EFA) was performed on one half of the data to identify factors using the R 'psych' package v 1.7.8 (Revelle 2017). EFA on the dog owner data was performed on 3 to 6 factors, since fitness measures (VSS and MAP)

showed inconsistent results. For the veterinary health practitioner EFA, both VSS and MAP suggested 2 factors.

Potential constructs from EFA were tested by confirmatory factor analysis (CFA) on the other half of the data using the R 'lavaan' package v 0.5-23.1097 (Rosseel 2012). The random split EFA/CFA procedure was repeated 10 times to investigate consistency of potential constructs. Identified factors were then manually inspected for relevance and compared to the pre-determined potential constructs.

3.3.3   Statistical analysis

Single items were analysed using logistic regression for questions with binary responses (R function 'glm' with family='binomial') and ordinal logistic regression for questions with ordinal responses ('polr' function from the 'MASS' R package). Dog weight group, sex and breed group, as well as owner gender, level of education, county (urban vs. rural), employment, medical profession and breeder status, were included as fixed factors, and dog and owner year-of-birth as covariates. Results from logistic regressions are reported as odds ratios with 95% CI.

Differences in proportions (e.g. dog owners stating tooth brushing vs chews as being important for dental health or veterinary health practitioners reporting anaesthetics and dental radiography equipment in relation to clinic size) were tested using $\chi 2$-tests. All tests were considered statistically significant at $p < 0.05$.

Construct scores were analysed using linear models (R function 'glm') and using Tukey adjustment for pairwise comparisons. Results reported as least squares means with 95% CI. The *Brush Attitude* and *Dental Health* models from the dog owner data included dog weight group, sex and breed group, as well as owner gender, level of education, county (urban vs rural), employment, medical profession and breeder status, as fixed factors. In addition, dog and owner year-of-birth were added as covariates. To investigate the association between *Dental Health* and breeds, a similar model was used, although excluding dog weight and breed groups.

From the veterinary health practitioner survey data, the *ChewFeed* and *Cleaning* constructs were analysed similarly, including profession (veterinarian vs veterinary nurse), gender, county (urban vs rural), size of clinic, and whether they treated dogs in their practice (sometimes vs often) as fixed factors. In addition, year-of-degree was added as a covariate.

4. Results

4.1 Response rates

The total number of dog owner respondents was 66,434, corresponding to a response rate of 32%. The total number of veterinarian and veterinary nurse respondents was 1,161 (32%) and 624 (38%) respectively. After removing incomplete answers (individuals with > 20% missing data among selected background questions), a total of 59,978 dog owners', 1,114 veterinarians' and 609 veterinary nurses' individual responses remained (Table 1).

4.2 Background characteristics of respondents

Background characteristics of veterinary health practitioners and dog owner respondents and their dogs are described in detail in Paper II.

In brief, the dogs were 4.9 ± 3.5 years of age (mean ± SD). All breed groups were represented. One-third (33%) of dogs weighed under 10 kg and a majority (78%) of all dogs were sexually intact. Dog owners were 49.9 ± 13.4 years of age, 75% were women and 25% were men. Almost half (46%) of all dog owners lived in urban counties (Stockholm, Skåne, Västra Götaland). Seven in 10 (70%) were employed or self-employed, 49% had studied at a university and 23% reported that they worked within a healthcare profession. One in twelve (8%) dog owners was also a dog breeder.

Veterinarians were 42.4 ± 12.8 and veterinary nurses were 40.8 ± 9.6 years old. One-third (34%) of veterinarians and one in 12 (8%) veterinary nurses had received their degree prior to 2000. Three in four (77%) veterinarians and almost all (97%) veterinary nurses were women. Six in 10 (62%) veterinarians and half (51%) of veterinary nurses lived in an urban

county (Stockholm, Skåne, Västra Götaland). Six in 10 (62%) veterinarians and nine in 10 (89%) veterinary nurses often encountered dogs in their professional role. Almost three in four (73%) veterinarians and almost all (96%) veterinary nurses worked in a clinic or animal hospital for dogs, cats and smaller animals, and of these, one-quarter (26%) of veterinarians and two-thirds (36%) of veterinary nurses worked at a clinic with 11 or more employed veterinarians.

4.3   Survey validation (Paper I)

The questionnaires were shown to have high content and face validity. Construct validity for dog owners' assessment of dental health was also confirmed, since the constructs were in agreement with previous studies of canine dental disease prevalence. The validation showed that the developed questionnaires could be used as accurate and reliable tools for measuring attitudes and practices regarding dental home care in dogs among Swedish dog owners, veterinarians and veterinary nurses.

4.3.1   Constructs

Constructs were identified using factor analysis and two predefined constructs from the dog owner questionnaire were confirmed: "Dog owners' attitudes towards brushing their dog's teeth" (Cronbach's $\alpha = 0.86$) and "Dog owners' assessment of their dog's dental health" ($\alpha = 0.76$). In the veterinary health practitioner questionnaire, two constructs were identified: "Veterinary health practitioners' attitudes towards dental chews and dental feed" ($\alpha = 0.78$) and "Veterinary health practitioners' attitudes and opinions on dental problems and dental cleaning/tooth brushing" ($\alpha = 0.73$).

4.3.2   Non-response analysis

The internal loss was $\leq 0.9\%$ in the dog owner questionnaire and $\leq 1.7\%$ in the veterinary health practitioner questionnaire on any single question, showing no evidence of systematic drop-out.

Non-response analysis showed a higher proportion of women in the sample of dog owners (74%) and veterinarians (80%) compared to the target populations (65% and 68% respectively). Veterinarians in the sample were also younger than in the target population (average 6 year difference, p < 0.0001). Mean ages of target and sample populations of dog owners were

different, but not likely to be relevant because of the small effect size (0.5 years). In contrast, gender and age distributions in veterinary nurses did not differ between sample and target. The geographic distribution by county differed between the target and sample distributions of dog owners (p<0.0001), with an overrepresentation of respondents from the Stockholm-Uppsala region. Among the 10 most common breeds in the sample and target populations, eight were identical. Results of non-response assessment are described in detail in Paper I.

4.4 Veterinary health practitioners' information regarding dental home care (Paper II)

Of the dog owners, 43% reported that they had at some point been recommended at the veterinary clinic to brush their dog's teeth (Fig. 7). About 28% of these owners stated that they were recommended both brushing and textiles to clean the dog's teeth. Dog owners reported that the veterinarian gave the recommendation in 50% of the cases, 15% stated that the veterinary nurse, and 27% reported both the veterinarian and the nurse gave recommendations.
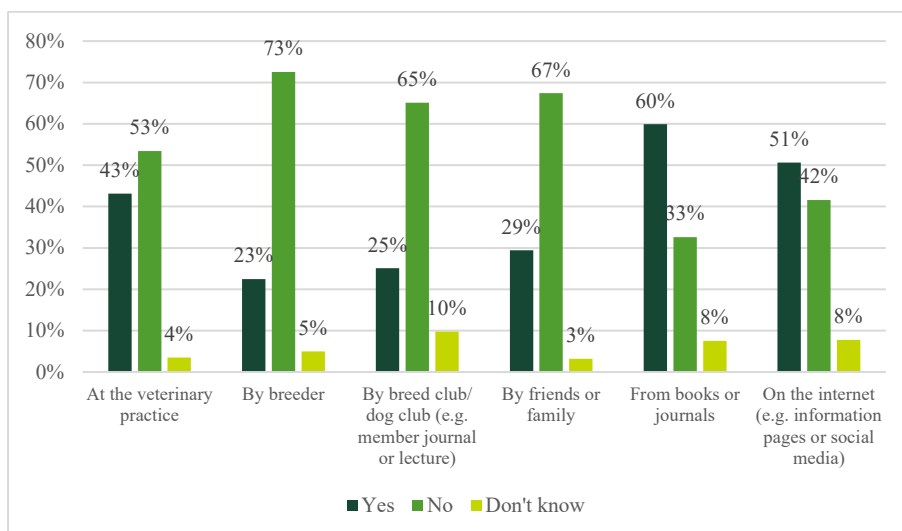

Figure 7. Dog owner survey: Have you ever been recommended, by any of the following, to brush/clean your dog's teeth? (Brushing refers to brushing with a toothbrush. Cleaning refers to cleaning with textiles, e.g. finger cloth, microfibre, other textiles or gauze).

Veterinarians and veterinary nurses reported that they predominantly (80%) gave information about tooth brushing in conjunction with visits for dental problems or dental cleanings. Of dog owners that had received a recommendation at the veterinary clinic to brush, 43% reported that they received information during a routine visit for e.g. yearly vaccination (Fig. 8). Moreover, 18% of the dog owners that had received recommendations to brush at the veterinary clinic answered that they received the recommendations at the puppy vaccination (Fig. 8), which corresponds to 7% of all dog owner respondents in the survey. One in four (26%) dog owners reported that they initially complied with the recommendation to brush but discontinued brushing after a while.
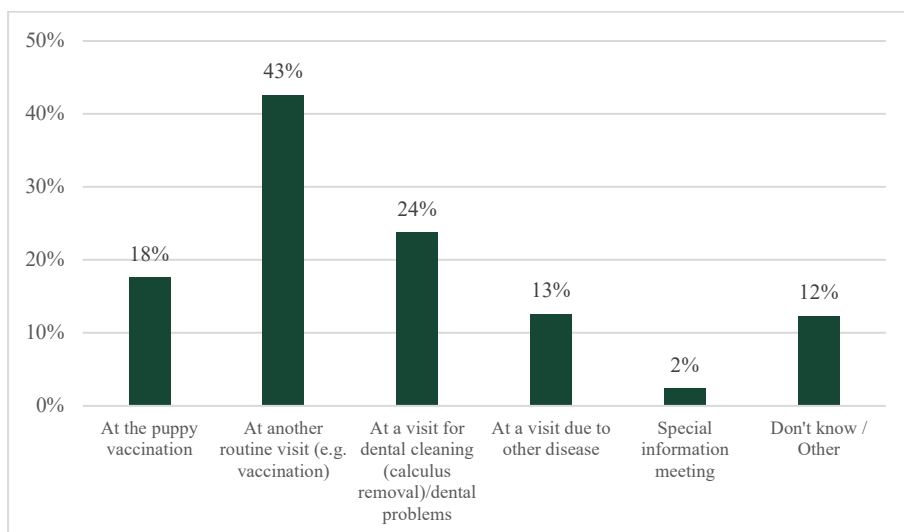

Figure 8. Dog owner survey: When you received the recommendation at the veterinary clinic to brush/clean your dog's teeth, what was the occasion? Several options can be specified.

Of the veterinarians, 23% reported that they sometimes supply written information concerning tooth brushing in dogs, and 6% of dog owners that reported having been recommended to brush stated that they had received written tooth brushing information.

Many veterinarians (30%) recommended a brushing frequency other than daily, e.g. every other day (5%) or as often as the owner had time for (9%). Furthermore, 38% of veterinarians stated that they never follow up on dental home care for the dogs.

In the free text, many veterinarians and veterinary nurses mentioned that they modify and adapt information to dog owners about dental cleaning depending on the breed and size of the dog, e.g. by recommending tooth brushing more often for smaller dogs.

4.5 Dental home care opinions and practices (Paper II)

4.5.1 Active dental home care

Tooth brushing was considered very important for good dental health in dogs by 29% of dog owners, 66% of veterinarians and 80% of veterinary nurses. The most important reasons for dog owners to brush their dog's teeth were to retain the teeth (67%) and that brushing is beneficial for the dog's general health (64%).

Veterinarians and veterinary nurses who often met dogs were more likely to state tooth brushing as important for good dental health. Veterinary health practitioners with a more recent degree had a more positive attitude towards dental cleaning/tooth brushing, and a more negative attitude towards dental chews/dental feed, than their counterparts.

Out of all dog owners, 9% brushed their dog's teeth four times a week or more (Fig. 9), and, in addition, 36% of dog owners in the study would never consider brushing their dog's teeth daily. Smaller dogs and dogs that received dental chews were more likely to have their teeth brushed more often. Of dog owners that reported very poor dental health in their dog, 16% brushed their dog's teeth four times a week or more.

Older dog owners and owners of younger dogs had a more positive attitude towards brushing their dogs' teeth than their counterparts. Some dog owners (8%) used textile, e.g. microfibre, at least once a week to clean their dog's teeth.
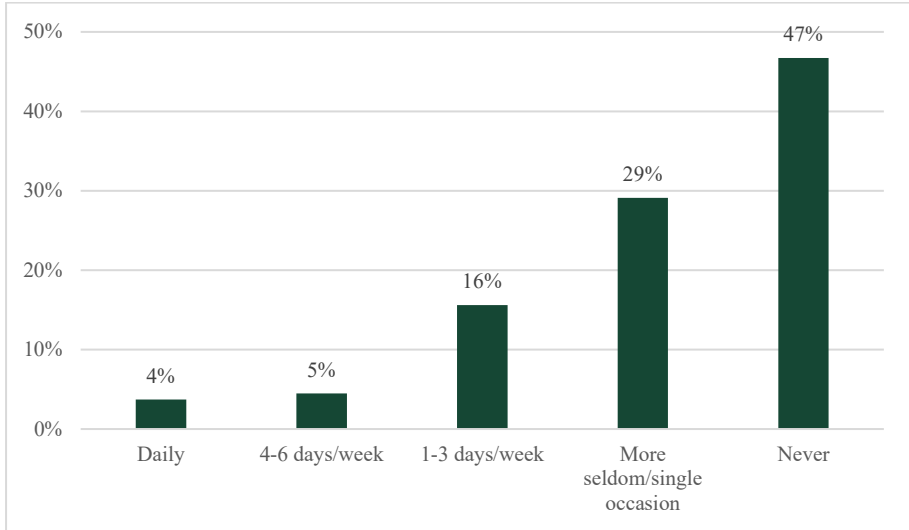
Figure 9. Dog owner survey: How often, in the last month, have you brushed your dog's teeth with a toothbrush?

4.5.2   Passive dental home care

Natural chews (e.g. rawhide, pig ears, etc.) were considered very important for good dental health by 29% of dog owners (Fig. 10). Dental chews, on the other hand, were considered very important by 18%, and 21% of dog owners fed their dog dental sticks at least 4 times a week.

About four in ten (43%) veterinary health practitioners sometimes recommended dental chews for good dental health. Veterinarians and veterinary nurses who often met dogs had a more negative attitude towards dental chews and dental feed than their counterparts.

Veterinary health practitioners as a group recommended natural chews (for dental health) more often than products that may have gone through clinical trials, i.e. dental chews (Fig. 11).
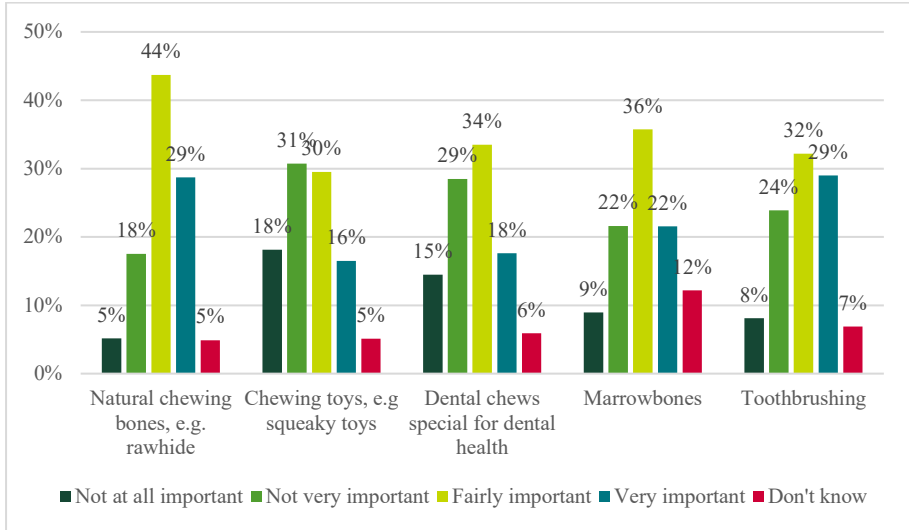
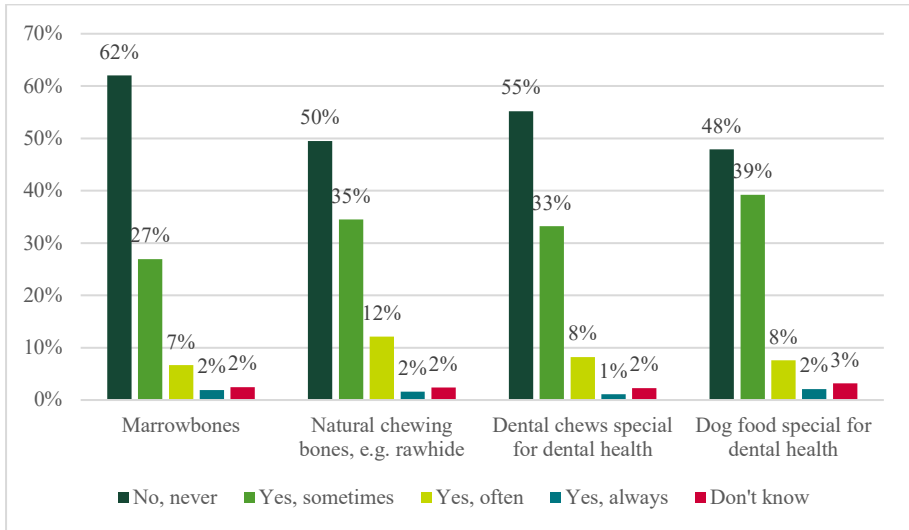*Figure 10*. Dog owner survey: What do you consider to be important to good dental health in the dog?

Figure 11. Veterinarian survey: Do you recommend dog owners to use any of the following to improve the dog's dental health?

4.6   Dog owners' assessment of dental health (Paper III)

Dental health was considered very important by 80% of dog owner responders, and 19% considered dental health fairly important. Of owners of dogs aged four years and older, 38% rated their pet's dental health as very good.

About half (48%) of all dog owners reported halitosis to some degree, and 37% of owners reported the presence of dental calculus in their dog. However, 11% didn't know if their dog had calculus. Of the owners who cleaned their dog's teeth, 35% reported occasional oral bleeding. According to dog owners, 8% of all dogs had experienced problems with gum disease/mobile teeth, compared to 21% of all dogs over eight years of age. Among Chihuahuas, 71% of dogs over eight years of age were reported by their owners to have gum disease.

Women perceived dental health (as analysed in construct) in their dog as being worse compared to men, and breeders perceived dental health in their pet as better than their counterparts. Younger dog owners and owners of older dogs perceived their dog's dental health as worse than their counterparts.

One in four (25%) owners sometimes or always experienced difficulties when inspecting their dog's teeth. The most common reason for these difficulties was stated as an uncooperative dog (79%).

4.6.1   Breed differences

Among breeds with ≥ 400 respondents, owners of German Shepherd Dogs, Flat Coated Retrievers and Rottweilers had the highest scores in the construct *Dental Health,* reflecting a perceived better dental health than owners of Chihuahuas, Yorkshire Terriers and Chinese Crested Dogs, who had the lowest scores (Fig. 12).

Among breeds with ≥ 100 respondents, owners of Briards (78%), Dobermanns (77%) and Giant Schnauzers (76%) were most likely to answer that their dog had very good dental health. The owners of a Prazský krysaríks (19%), Chinese Crested Dogs (25%), Pomeranians (25%), Italian Greyhounds (25%) and Chihuahuas (27%) were least likely to report very good dental health. The owners of Pugs (34%), Chihuahuas (21%), Yorkshire Terriers (17%), Pomeranians (16%) and Papillons (16%) were most likely to report that it was very difficult to inspect the dog's teeth.
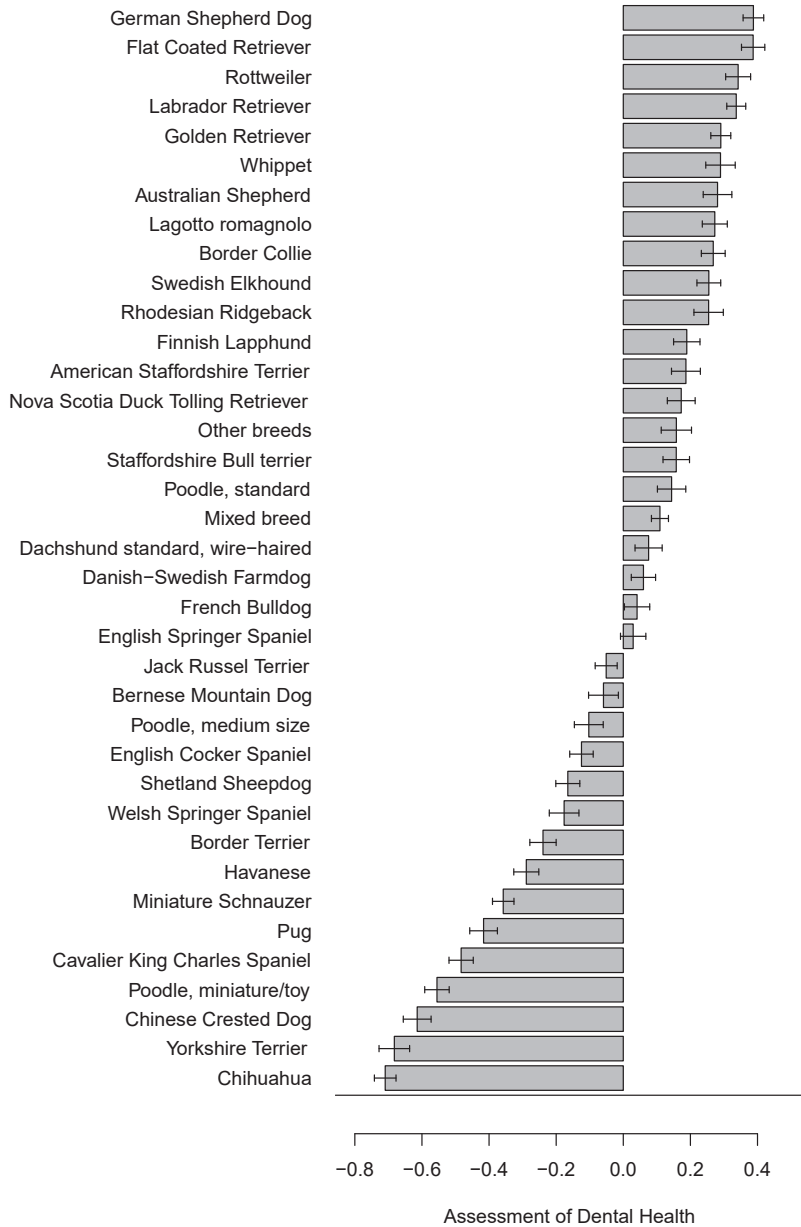
Figure 12. Association of breeds with owners' assessed symptoms of their dog's dental health. Reported for breeds with ≥400 respondents. A higher construct score represents a relatively better perceived dental health. Scores should only be compared within figure. Note that negative scores do not automatically reflect a negative assessment of dental health.

4.6.2 Other diseases

Among the alternatives provided in the questionnaire, the most common concurrent diseases were skin disease (3.9%) and joint disease (3.7%). Concurrent diseases reported by ≥100 dog owners were investigated further. In particular, cardiac disease, renal disease and hepatic disease were found to be associated with a more negative dental health assessment.

4.7 Professional dental cleaning routines in small animal clinics (Paper IV)

Regular dental cleaning under general anaesthesia was considered important (fairly or very) for good dental health in dogs by 43% of veterinarians and 49% of veterinary nurses. Moreover, 49% of veterinarians and 47% of veterinary nurses stated that it was sometimes important.

In total, 27% of veterinarians and 18% veterinary nurses who regularly met dogs in their profession stated that dental cleaning was performed under sedation at their workplace. Dental cleaning performed under sedation was more common in smaller veterinary clinics and among older veterinary health practitioners.

Of veterinary health practitioners reporting that professional dental cleaning was performed at their workplace, 98% of veterinarians and 99% of veterinary nurses reported that teeth were sometimes extracted during the procedure. Of these respondents, 70% stated that only veterinarians, 4% that only veterinary nurses, and 26% that both veterinarians and veterinary nurses performed dental extractions.

Of respondents that reported dental extractions being performed at the veterinary clinic, 30% of veterinarians and 9% of veterinary nurses stated that they did not have access to dental radiography equipment at the clinic.

Dog owner respondents reported that 13% of dogs had previously been anaesthetised for dental cleaning. Among dogs older than eight years, this number was 31%.

5. Discussion

This thesis presents large-scale questionnaire survey data on attitudes, opinions and practices regarding dental care in dogs, thereby providing a unique basis for future improvements in the field of dental home care and dental health for dogs.

5.1 Survey validation (Paper I)

The validation protocol used in this study was developed and conducted according to current evidence-based recommendations, taking into account several aspects of questionnaire validity, thus ensuring high data quality. The formulation of questions and response options based on survey methodology guidelines is fundamental in order to avoid bias. Unfortunately, questionnaire surveys are still commonly performed without quality control of gathered data.

The validation procedure in this study generated comments, which resulted in revision of the questionnaires to increase clarity and simplicity throughout the process. Numerous textbooks in the field of survey methodology suggest good practice in the development and validation of questionnaire surveys (Ejlertsson 2005; Marsden & Wright 2010; Dillman *et al.* 2014; Berntson *et al.* 2016; Wenemark 2017). However, in the process of developing and validating the questionnaires for the current study, we saw a need for general, and preferably international, consensus guidelines regarding validation protocols for questionnaire surveys in research, which are lacking today.

Test reliability was not assessed by inter-rater agreement, since the collected data derived from fixed response scales and therefore were considered unaffected by assessor. Moreover, test-retest assessment was not

performed, as a second measurement of dental health in dogs would likely be affected by the first survey raising respondent awareness, and was therefore considered sensitive to repeated measurement.

There is a potential risk of respondents being more interested in the subject than the average population. Also, using pre-formulated sentences as response options entails a risk of misinterpretation of opinions. The validation procedure was performed to minimise these risks.

The use of vague response options, such as "sometimes"/"often" or "not common, very common", for several of the survey questions poses limitations on the possibilities for quantification of actual frequencies. However, this was an informed decision based on the aims of the study, i.e. to investigate attitudes, opinions and routines.

The non-response analysis, used to assess the representativity of results, indicated some differences between the sample and the target population, e.g. in a lower proportion of men in the sample. Target and sample age distributions were similar, albeit with an underrepresentation of the youngest and oldest dog owners among the respondents. These discrepancies need to be taken into account when interpreting some results, especially the responses that are presented for the respondent group as a whole. However, the sample size was very large, all subgroups were well represented and the overall representativity was regarded to be satisfactory.

In conclusion, the developed questionnaires were considered to be accurate and reliable tools for measuring attitudes and practices regarding dental care in dogs.

5.2 Veterinary health practitioners' information regarding dental home care (Paper II)

A vast majority of veterinarians and veterinary nurses (94% and 97% respectively) stated that they often encountered dental problems in dogs (paper II). Surveys of veterinarians' and veterinary nurses' opinions and practices regarding dental care in dogs are scarce. However, the perception of dental disease and periodontal disease as very common in veterinary practice is strengthened by two previous studies (Demeijer *et al.* 1991; Johnston 2012).

Despite these numbers from the veterinary practitioners, less than half (43%) of the dog owners reported having been recommended to brush their

dog's teeth at a veterinary clinic. The majority (80%) of veterinary health practitioners reported giving recommendations in conjunction with a visit for dental cleaning/problems. This highlights substantial room for improved routines among veterinary practitioners concerning dental home care information. Recommendations for tooth brushing, in the majority of cases, appear to be received far too late for prevention of periodontal disease. To maximise health benefits, information about tooth brushing should be part of every puppy visit to the clinic.

The results show that veterinarians and veterinary nurses recommend both textiles and brushes to clean the dog's teeth. However, since studies are lacking both in humans and dogs, the use of textile is currently not evidence-based and the recommendation should be used with caution. Further studies are needed on the effectiveness of e.g. microfibre cloth as a means of cleaning dog's teeth and preventing periodontal disease.

Owners of breeds with an increased risk of periodontal disease (such as Chihuahuas (O'Neill *et al.* 2020), Yorkshire terriers (Wallis *et al.* 2019) and Miniature/Toy poodles (Hoffmann & Gaengler 1996) more commonly reported that they received recommendations to brush at the veterinary clinic. However, the recommendations were again, unfortunately, not received at the puppy vaccination but at veterinary visits for dental cleanings/problems, i.e. when problems were already manifested (data not published). All dogs benefit from daily tooth brushing (WSAVA 2018). However, knowing what breeds have an increased risk of dental disease may be helpful in conveying early information and providing extra support in dental home care for individuals at higher risk.

Interestingly, veterinarians and veterinary nurses often recommend brushing frequency other than daily, e.g. once a week, contrary to the gold standard (WSAVA 2018). This may reflect a lack of knowledge among veterinary health practitioners. However, the majority of dog owners would actually consider brushing daily, and many had initiated brushing only to discontinue after a while, indicating that veterinarians and veterinary nurses may very well underestimate owners' willingness and capability to perform tooth brushing on their pet. Many owners expressed that their dog's uncooperative behaviour contributed to difficulties in handling the dog's mouth. Based on these results, veterinary practitioners should strive to provide early intervention with proper guidelines and support in order to improve dental home care in dogs.

Studies on adherence to veterinary dental home care recommendations are scarce. However, in one study, half of the dog owners (27/51) still brushed their dog's teeth several times weekly, or even daily, a year after having received a recommendation (Miller & Harvey 1994). Hale (2003) discusses factors with an impact on performed dental home care, e.g. the owner's relationship with the dog, financial issues and the dog's temperament. In the present study, written veterinary information about tooth brushing was only sparsely used, and follow-ups were rare. This is very unfortunate, since educational material and follow-ups have been shown to have a positive impact on adherence (Costa *et al.* 2015). In addition, it was more common for veterinarians, rather than nurses, to give recommendations, contrary to the routines in human dentistry, where dental hygienists work solely with preventative home care, including motivation, techniques and follow-up. This practice may be a way forward in veterinary clinics as well, in which case veterinary nurses could play a fundamental role as providers of this service.

5.3   Dental home care opinions and practices (Paper II)

With only 4% of dog owners brushing daily, tooth brushing is clearly inadequate. This low number may in fact even be an overestimation, due to social desirability bias and that owners more interested in dental health may have been more prone to answer the questionnaire. The frequency of brushing in a large population of privately owned dogs has not previously been published in peer-reviewed literature. However, the low brushing frequency is supported by a Canadian market company, which reported similar numbers (Ipsos 2016). The results of our study clearly shows there is room for improvement.

The efficiency of tooth brushing depends on the type of toothbrush, method of brushing and frequency and time of brushing, and also the use of additional aids such as mouthwashes (Digel *et al.* 2020). However, even when brushing twice a day, most humans do not reach an optimal level of plaque control; a mean plaque reduction of 42% has been shown in a meta-review (Van der Weijden & Slot 2015). Tooth brushing in dogs requires both training and skill in order to reach all teeth surfaces, but there are no published studies investigating the quality of brushing in privately owned dogs. Although the quality of tooth brushing was not specifically addressed

in our study, many dog owners reported difficulties when inspecting the dog's mouth, indicating that the efficacy of brushing may be low.

The predisposition of smaller dogs and certain breeds to periodontal disease may be one reason why owners of smaller dogs brushed more often in our study, but they were also the ones having most problems inspecting/handling the dog's teeth and experiencing worse dental health, indicating the need for support.

Veterinarians and veterinary nurses often recommended marrowbones to improve dental health, and dog owners also consider marrowbones as a way of caring for the dental health in their dog. In fact, as many as 25% of dog owners provided their dog with marrowbones once a week or more often for this purpose (unpublished data). However, there is little or no evidence supporting the use of marrowbones to promote dental health; on the contrary, it may in fact be harmful (Roudebush *et al.* 2005). Consequently, veterinary practitioners should not recommend the use of marrowbones, either as a pastime or to improve dental health.

Dog owners who brushed more frequently also gave dental chews more frequently, suggesting that owners more interested in dental home care may use both active and passive means of plaque-control. This is in accordance with general recommendations by the WSAVA, where passive care may be seen as a complement, and not as a substitute, to tooth brushing. However, considerably more dog owners used passive dental home care than active. Since passive dental home care is not enough to prevent oral inflammation (WSAVA 2018), this could mean that a large number of dog owners experience a false sense of security and that dental problems may go undetected.

The use of natural chews was considered important by many dog owners for their dog's dental health, and they were used extensively, supposedly as a reward, as a pastime and to promote dental health. However, there is a lack of studies supporting the use of these kinds of chews for improving dental health and this use is therefore not based on evidence.

Veterinarians with a more recent degree were considerably more positive towards tooth brushing in dogs compared to their counterparts. This may in fact reflect a paradigm shift in the veterinary community towards attributing higher importance to dentistry and dental home care, which is also reflected in veterinary education (personal communication Ann Pettersson).

5.4   Dog owners' assessment of dental health (Paper III)

The majority of owners of dogs over 3 years of age rated their dog's dental health as less than very good, implying a deviation from optimal dental health. Since only 13% of dogs in the study had been anaesthetised for dental cleaning and examination, significant under-treatment of dental disease can be assumed, suggesting that many dogs may be subjected to undue suffering and discomfort.

Gingivitis, in response to dental plaque formation, may occur within two days without dental cleaning (Tromp *et al.* 1986a), and the high prevalence of halitosis and occasional oral bleeding when brushing observed by dog owners indicates that persistent gingivitis was common among their dogs. Considering the low brushing frequency, this was not surprising.

Dog owners commonly experienced difficulties when assessing their dog's teeth, mainly due to an uncooperative dog, which, in addition to a lack of knowledge, may be one reason for many not knowing if their dog had dental calculus.

Eight per cent of all dog owners reported that their dog had gum disease. Of these, most had lost teeth, and these cases are therefore likely to represent periodontitis and not just gingivitis. This prevalence is in agreement with previous patient record studies (O'Neill *et al.* 2014; Summers *et al.* 2019). However, primary care data is considered to underestimate the true extent of dental problems (Wallis & Holcombe 2020). Clinical examination of the oral cavity in non-anaesthetised dogs provides only limited information concerning periodontal health. Furthermore, oral examination may not be part of every visit, and/or findings may not be recorded in the database. Other studies on anaesthetised dogs have shown a periodontal disease prevalence of 44-100% (Wallis & Holcombe 2020). One recent large study showed an overall prevalence of periodontal disease of 86%, with 44% having gingivitis and 42% periodontitis at some stage (Stella *et al.* 2018). Many studies do not distinguish between gingivitis and periodontitis, both in the periodontal disease complex, and the methodologies and study populations vary extensively. For this reason, it is difficult to know the accurate prevalence of gingivitis and periodontitis respectively.

Some breeds previously known to be predisposed to periodontal disease, e.g. Poodles, Yorkshire Terriers and Miniature Schnauzers, were identified as breeds at risk in our study. This is in line with previously reported periodontitis prevalence of 98-100% in these breeds (Hoffmann & Gaengler

1996; Marshall *et al.* 2014; Wallis *et al.* 2019; O'Neill *et al.* 2020; Wallis & Holcombe 2020). Our study also identified perceived worse dental health in some other breeds not previously reported in the peer-reviewed literature, such as Chinese crested dogs, Pugs and Havanese. Although studies are lacking, these breeds have been observed in practice by many clinicians to be predisposed to periodontitis. Previous studies have also suggested breed differences in terms of the number of teeth, and which teeth, are more prone to be affected by periodontal disease (Wallis & Holcombe 2020). Further studies are needed to investigate breed-specific dental health.

Reported instances of cardiac, hepatic or renal disease in the dog were associated with poorer assessed dental health. Concurrent disease or medication may affect the dog's dental health status. In addition, owners of dogs with other severe disease may be more observant overall regarding their pet's health and therefore more likely to detect oral disease. Associations between worse periodontal health and a number of diseases have also been described in humans (Hajishengallis 2014). Causality is seldom evident (Kim & Amar 2006), however, and the underlying mechanisms describing the relationship between general health and dental health in dogs remain to be elucidated.

5.5 Professional dental cleaning routines in small animal clinics (Paper IV)

Professional dental cleanings were commonly performed under sedation only, as stated by the respondents in the study. According to general national and international guidelines, dental cleaning should be performed under general anaesthesia with the patient connected to a closed anaesthetic circle (WSAVA 2018). Consequently, improvements are needed regarding anaesthetic routines during dental cleaning in veterinary practices.

Dental extractions were reportedly performed by both veterinarians and veterinary nurses in the same clinic. Dental extractions are considered to be surgical procedures and should, according to Swedish legislation, be performed by veterinarians (Jordbruksverket 2013), with the exception of mobile, single-rooted teeth that may be regarded as a simple procedure and can therefore be delegated to a veterinary nurse (SSDT 2014). In addition, The American Veterinary Dental College (AVDC) states that "only veterinarians shall determine which teeth are to be extracted and perform

extraction procedures" (AVDC 2006). However, it may also be common internationally for veterinary nurses to perform dental extractions, even though it may not be legal (Harvey & Cameron 2019). Our results may indicate that veterinarians performed the more complicated extractions, whereas veterinary nurses performed simple extractions, in line with Swedish legislation.

Guidelines clearly state that dental radiographs should precede any extractions, and post-operative radiographs are also recommended. However, in our survey, dental extractions were commonly performed without access to this equipment, with the risk of potential complications. Our results suggest the need for educational efforts to increase the awareness among veterinarians and veterinary nurses regarding guidelines and recommendations in dental care for dogs. Such measures should reduce the risk of complications during dental extractions (Verstraete *et al.* 1998).

Only 13% of the dogs in our study had previously been anaesthetised for dental cleaning, which shows that few dogs are receiving the yearly examinations by a veterinary dentist that are recommended by the AAHA. Thus, there is room for improvement regarding the frequency of routine veterinary dental appointments for dogs.

About half of the veterinary health practitioners stated that regular professional dental cleaning is only sometimes important. One explanation for this may be that cleanings are not considered important until dental problems have been confirmed. It would be unfortunate if this were the case, since prevention of dental problems is always preferable to treatment of already existing disease. Another possibility may be that veterinarians and veterinary nurses deem professional dental cleanings to be more important in smaller dogs or certain breeds, known to be predisposed to periodontal disease. Moreover, there may also have been a tendency among veterinarians and veterinary nurses in the past to trivialise dental disease.

5.6 Limitations

Questionnaire surveys inevitably contain bias, such as recruitment bias, social desirability bias and acquiescence bias. Using guidelines for survey construction and extensive validation, we have endeavoured to reduce bias as far as possible. However, the potential for bias should be taken into account in the interpretation of the results.

The target population for the veterinary/veterinary nurse survey consisted of individual respondents. Several respondents may work in the same veterinary clinic or hospital, potentially leading to over-representation of especially large workplaces. Consequently, the results obtained may not accurately reflect differences at a clinic level.

Furthermore, the presented study was performed in a Swedish social and cultural context, which should be taken into account in any international comparisons.

Moreover, and importantly, clinical veterinary examinations were not performed and dental health assessments made by dog owners could, consequently, not be validated. These specific results therefore reflect the dog owners' perceived and self-reported dental health of their dog.

6. Conclusions

The results from this study constitute an important foundation for future development of prophylactic strategies, with the ultimate goal of improving dental health, and thereby animal welfare, in dogs.

In summary, the conclusions in this thesis are that:

- Development and validation of questionnaires according to survey methodology guidelines led to high quality data regarding dog owners', veterinarians' and veterinary nurses' attitudes, opinions and practices regarding dental care in dogs.
- Dog owners with smaller dogs, older dogs and certain breeds known to be predisposed to periodontal disease, assessed their dog's dental health as worse than their counterparts.
- A majority of Swedish dog owners do not provide adequate dental home care for their dog.
- A lack of knowledge regarding dental care in dogs was revealed both among dog owners and veterinary health practitioners.
- Dog owners were more positive towards passive dental home care compared to veterinary health practitioners, and veterinary health practitioners were more positive towards tooth brushing compared to dog owners.
- There is a need for education and support for dog owners and training of dogs to accept dental home care procedures.
- Recommendation routines regarding tooth brushing in dogs, from veterinary health practitioners to dog owners, are insufficient, with information conveyed too late and too infrequently.
- Contrary to recommendations, professional dental cleanings in dogs under sedation only are common in Sweden.

- Contrary to recommendations, dental extractions in dogs without access to dental radiography equipment are common in Sweden.

The immense outreach of our survey to more than 200,000 dog owners has probably focused dog owners' attention on their dog's dental health, both directly via the questionnaire survey and indirectly via media attention to this study. This attention has hopefully inspired dog owners to take dental problems and dental care in dogs seriously, and to improve dental care through increased inspection and prophylactic home care.

6.1 Implications

Today, dental problems are one of the major welfare issues for dogs (Summers *et al.* 2019), which emphasises the importance of educating dog owners to recognise and prevent dental diseases. The surveys clearly showed that dental health in many ways is a neglected area and that tooth brushing in dogs is inadequate.

There may be many obstacles as regards increasing adherence to tooth brushing in dogs; a tradition of not brushing, opinions about tooth brushing as un-natural, lack of knowledge about dental disease, practicalities in handling, etc. However, the study results showed that many owners are willing to brush their dog's teeth. As a means of increasing dog owners' motivation to brush, recommendation strategies could lift the owners' reasons to brush, primarily that it is good for general health and that it is a way to retain teeth. Furthermore, information about dental care and practical training, e.g. at the veterinary clinic, may facilitate the implementation of daily tooth brushing. Veterinary clinics, both large and small, have immense potential here to fill the gap that exists in preventative veterinary dentistry.

Furthermore, veterinary dentistry could build on the experiences from human dentistry, where regular professional dental assessment and cleaning together with daily dental home care are the basis for good dental health throughout life. Introducing the role of a dental hygienist for professional dental cleanings in veterinary clinics, along with the praxis of regular visits to the pet dental hygienist to assess and discuss dental home care routines, have the potential to greatly improve dental health in dogs.

Moreover, in human dentistry, the importance of motivating clients to change behavior regarding dental home care is acknowledged in national

guidelines, and so-called Motivational Interviewing (MI) is an evidence-based method recommended for this purpose. If implemented in veterinary practice, such communication practices may be a way to increase adherence to dental home care in dogs.

6.2   Future studies

Follow-up studies to investigate dental home care in dogs over time would be highly interesting, especially to evaluate whether measures taken to increase knowledge and the implementation of dental home care have had the desired effect.

International comparisons regarding canine dental care are lacking today and would also be of great interest for exploring differences in national and cultural contexts.

Easy-to-use tools for home assessment of dental health could, besides being useful in research settings, contribute to an increased incentive for home care. A validation of the Dental Health construct against veterinary clinical assessment of dental health may therefore prove to be useful.

In addition, an analysis of the many free text answers in the surveys could add new insights regarding e.g. motivational factors for dog owners to improve the dental care for their dog.

Evidence-based methods to improve client adherence regarding dental home care in dogs are needed and are a field of future research. Moreover, studies on training methods aimed at facilitating the dog's acceptance of tooth brushing are suggested as an important step towards increasing tooth brushing in dogs.

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Popular science summary

Periodontal disease, or gum disease, is very common in dogs as well as in people. The disease is characterised by an inflammation of the tooth's supportive tissues and, if untreated, may eventually lead to tooth loss. The best way to prevent the disease is daily tooth brushing. Chewing natural bones or e.g. dental chews is not enough to prevent gum disease in dogs. Besides tooth brushing, regular visits to a veterinary dentist are recommended to maintain good dental health throughout the dog's life.

To investigate dog owners', veterinarians' and veterinary nurses' attitudes, opinions and routines regarding dental health and dental care in dogs, we conducted a questionnaire survey. The questionnaire was sent out to all dog owners, veterinarians and veterinary nurses with e-mail addresses in national registers, which resulted in more than 68,000 responses.

The results showed that only 4% of dog owners brushed their dog's teeth daily and that less than half of the dog owners had received a veterinary recommendation to brush. Furthermore, the recommendation was often given too late, when dental problems had already occurred. Smaller dogs, dogs of certain breeds and older dogs were assessed by their owners to have worse dental health overall, which is in accordance with gum disease being more common in these groups.

To conclude, there is room for improvement in dog owners' dental home care regimes, and veterinary practitioners have considerable potential to inform, motivate and support dog owners in their efforts to brush their dog's teeth. This could drastically improve dogs' dental health and overall wellbeing.

Populärvetenskaplig sammanfattning

Parodontal sjukdom, dvs. tandköttsinflammation och tandlossning, är mycket vanligt hos hundar precis som hos människor. Sjukdomen innebär en inflammation av tandens stödjevävnad och om den inte behandlas kan den så småningom leda till att tänder förloras. Det bästa sättet att förebygga sjukdomen är daglig tandborstning, medan att tugga på tuggben eller s.k. dentaltugg inte är tillräckligt för att förhindra tandlossning. Förutom tandborstning rekommenderas regelbundna besök hos veterinären för att upprätthålla en god tandhälsa under hela hundens liv.

Vi har genomfört en enkätundersökning med frågor om attityder, åsikter och rutiner om tandhälsa och tandvård hos hund. Enkäten skickades ut till alla hundägare, veterinärer och djursjukskötare med e-postadress i nationella register och vi fick tillbaka över 68 000 svar.

Studien visade att bara 4% av hundägarna borstade sin hunds tänder dagligen och att mindre än hälften av hundägarna hade blivit rekommenderade hos veterinären att borsta. Dessutom gavs ofta rekommendationen att borsta först när tandproblem redan uppstått, alltså för sent för att förebygga sjukdom. Små hundar, hundar av särskilda raser och äldre hundar bedömdes ha sämst generell tandhälsa, vilket stämmer med tidigare studier som visat att dessa hundar har ökad risk för tandlossningssjukdom.

Sammanfattningsvis finns det utrymme för förbättringar i hundägares hemtandvårdsrutiner för sina hundar och vi ser också att det finns en underutnyttjad potential för veterinärer och djursjukskötare att informera, motivera och stötta hundägarna i hundens hemtandvård. Detta skulle kunna förbättra hundars tandhälsa och allmänna välmående väsentligt.

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Dental problems, including periodontal disease, are very common in dogs. Today, daily tooth brushing is the gold standard for dental home care in dogs. Questionnaires regarding dental care were developed, validated, and distributed to all registered Swedish dog owners, veterinarians and veterinary nurses. Responses were received from over 68 000 individual participants. This thesis presents their attitudes, opinions and routines regarding dental care in dogs, providing a basis for future improved prophylactic strategies.

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