THESIS

Martine Lefstad
2021

Department of Physiology and Biochemistry
University of Veterinary Medicine

Exaggerated breeding and its health consequences in dogs, with a special focus on brachycephalic conformation

By

Martine Lefstad

Supervisor:

Dr. Jócsák Gergely, PhD

Budapest, Hungary

2021

Table of contents

1. Terms and definitions

BOAS: Brachycephalic obstructive airway syndrome

C: Conformation-related disorder. Disorder reported resulting directly from selection for a conformational trait.

CD: Inherited disorder worsened by a conformational trait.

Chiari-like malformation: Prolapse of any part of the hindbrain through the foramen magnum.

D: Non-conformational disorder. Disorder reported resulting from inheritance only.

FFP: Folded flap palatoplasty

GISID: Generic Illness Severity Index for Dogs

HCT: Hematocrit

Hemivertebra: Vertebral anomaly caused by lack of formation of one half of a vertebral body.

HGB: Hemoglobin

Hydrocephalus: A build-up of fluid in the brain.

IGF-1: Insulin growth factor-1

IVDD: Intervertebral disc degeneration

Kyphosis: Exaggerated outward curving of the thoracic region of the spine

LATE: Laser-assisted turbinectomy

MMS: Modified multilevel surgery

OFA: Orthopedic Foundation for Animals

PCV: Packed cell volume

RBC: Red blood cells

ROS: Reactive oxygen species

Spina bifida: A embryonic neural tube defect, where the spine and spinal cord don't form and close properly, leaving them open.

Syringomyelia: Accumulation of fluid within a cyst or a syrinx within the spinal cord.

TBFVL: Tidal breathing flow-volume loop

TEG: Thromboelastogram

TMS: Traditional multilevel surgery

Transitional vertebra: A vertebra that has undetermined characteristics and features of vertebrae from adjacent vertebral segments.

WBBP: Whole-body barometric plethysmography

2. Introduction

In this literature review, I'm focusing on how over-bred dogs changed anatomy and physiology have affected their health and well-being, with a special focus on the brachycephalic conformation.

Dogs became our companions around 40,000 – 15,000 years ago, although no specific origin story is known (Serpell, 2021) From the time of domestication until today, a lot has happened with their conformation. In the early beginning, it was practical and smart to select wolves with a mild temperament and decreased aggressiveness. After a while, wild living wolves and domesticated wolves got so different they no longer were the same species.

As *Canis lupus familiaris* was created, humans started to use them for different tasks and therefore selected for further differences in behavioral traits and anatomy. The bigger and bigger morphological differences caused the domesticated wolf to divide into different breeds, all with the help of humans. This process has been ongoing since then and continues still. In modern times dogs have lost a lot of their functional role as they had in society before and have gradually taken more of a role as companions to people. This has caused a change in the artificial selection of dogs to be bred as well. The importance of functionality has decreased and given way to higher importance in looks and with that the consequences that follow.

Today the breeding has turned extreme for several breeds. As it is not as important for them to be functional but rather look a certain way for becoming "best in show" or satisfy the public wishes, the general health in many breeds has declined, and the look has become unrecognizable compared to when they first were created. There are set rules for ethical breeding, which says that animals should be functional, healthy, and free from hereditary qualities which affect them negatively, as stated in the Norwegian animal welfare act, but this is not regulated or upheld in any specific way in most countries today. Over-breeding has changed the looks, conformation, anatomy, and physiology to the extreme in certain dogs and other animals kept mainly for companionship, for no other reason than making them visually appealing to people.

The aim of this literature review is to understand how the health and wellbeing of certain breeds, especially those affected by brachycephaly have changed during selective breeding. and the reason behind breeding them, both in the past and today. Even when we know the

increased morbidity this conformation causes. What the future for these breeds hold, and people's attitudes in public, veterinary medicine, and kennel clubs for improving the quality of life for pedigree breeds.

3. History of pedigree breeds

During our history, the dog has had several different roles such as hunting, therapy, herding, military, rescue, security, and research. Selective breeding has helped create dogs for all these purposes. In the last 100 years, dog shows have increased in popularity, and current selective breeding typically focuses on physical appearances rather than function. Breeding today has shown a loss in genetic variation in several breeds of dogs (Jansson & Laikre, 2014). A reason for this is that during the late 1800s kennel clubs were formed. These had a set of rules to control breeding. To register a dog, both parents had to be registered as well, successfully isolating each breed and narrowing the gene pool further. Standards were established to describe the ideal physical representation of the breed. Following this period many new breeds were created, and today around 400 breeds are recognized (Parker, 2012). A pedigree dog is a purebred dog where ancestry is recorded.

The health issues the different breeds face can be divided into conformational related disorders and non-conformational-related disorders. Depending on if the disorders have a clear connection with the breed standard or not. Selective breeding has changed the visual characteristics of the dogs and reduced the gene pool to which the desired characteristics will be produced and with that the increased prevalence of breed-specific diseases.

When compared to mixed-breeds, purebreds have a lower average life expectancy as reported in several objective studies. Small breed crosses are the ones who have been reported to have a higher average life expectancy. This is due in part to the inverse relationship between body size and life expectancy. Reduced longevity does not necessarily mean a decreased quality of life. There is, however, substantial evidence that dogs of mixed breeds have fewer veterinary bills, which suggests that they suffer less from illness (Rooney & Sargan, 2010). A 1997 study in Denmark of purebred and mixed-breed dogs, showed a higher median life expectancy for mixed breeds, than the entire population with 11 years as opposed to 10 years. However certain breeds, like the Shetland sheepdog, dachshund, and poodle had an even higher median life expectancy of 12 years. The giant breed, Bernese Mountain dog had the lowest median age of 7 years (Proschowsky et al., 2003).

In pedigree dogs, disorders not related to breed standards account for above 75% of all inherited diseases. The high prevalence of inbreeding, and especially the reuse of popular sires is said to be the cause of that (Farrell et al., 2015). In this text the different disorders will be described by C = conformational related, CD= inherited but worsened by

conformation and D= inherited, non-conformational. In a study of the top 50 breeds in the UK in 2007, the German shepherd was the most susceptible to inherited disorders overall (C, CD, and D). Of the top 50 breeds, 33 of them could be categorized as brachycephalic (Asher et al., 2009)

3.1 Conformational related disorders

Of the UK's top 50 Kennel Club–registered breeds, most conformation-related problems are associated with breeds such as Bulldog, Pug, and Basset hound. The brachycephalic breeds have been linked with many conformational-related disorders. The head shape includes stenotic nares, skin fold dermatitis, elongated soft palate, and hypoplastic trachea in many cases. Brachycephalic obstructive airway syndrome (BOAS) is a combination of all these signs with gradings of different severity. Certain breeds of this formation also have a large head to pelvis ratio which can be linked with dystocia or problems giving birth (Asher et al., 2009).

Other exaggerated traits, that may intercept with the quality of life is a juvenile, rounded skull shape, long ears, excessive skin folds, screw tails, and cosmetic hair ridges which causes neural defects as seen in Rhodesian ridgeback, as well as characteristics that limit the animal's ability to act, communicate, and interact normally (Rooney & Sargan, 2010)

Some extreme phenotypes which have been shown to lead to health issues are giant, toy, brachycephalic and chondrodystrophic conformation.

3.1.1 Giant conformation

Large breeds have been shown to have disorders related to excessively rapid bone growth. Osteochondrosis is caused by the bones growing too quickly for their blood supply to keep up, resulting in the bone tissue dying (Rooney & Sargan, 2010). Increased prevalence of hip and elbow dysplasia has been documented as well. These disorders are polygenic, in which environmental factors are important. Exercise and diet have been shown to reduce the occurrence and severity of these afflictions (Asher et al., 2009).

Many large breeds have a deep-set chest, and this can cause gastric issues as gastric dilatation-volvulus (GDV), a life-threatening disease where the stomach twists around itself,

cutting off the blood supply and obstructing the gastrointestinal tract (Rooney & Sargan, 2010). Food sensitivities are also seen at a higher prevalence. Giant breed dogs, compared to smaller breeds have been shown to present a more developed caecum and colon, which causes a relatively longer transit time of feed. This in turn causes large breeds to form softer feces with more moisture than small breed dogs. This can be explained by the increased fermentation that happens during longer transit time. In addition, more by-products, increased intestinal permeability, and reduced sodium absorption can make the gastrointestinal tract more sensitive (Weber et al., 2017).

Giant conformation in dogs has been linked to decreased life span compared to medium and especially smaller dogs. This is the opposite of most mammalians, as larger organisms have been known to live longer than small ones. Insulin growth factor-1 (IGF-1), which promotes growth has been proposed to affect the lifespan of large breed dogs, by them having a higher concentration and different type of signaling, compared to smaller and medium-sized dogs. A higher concentration of IGF-1 is expected to increase oxidative metabolism and in turn increase the generation of reactive oxygen species (ROS), as have a prolonged growth period. A faster growth rate and longer developmental time would result in increased cell turnover, which is necessary for continuous growth, and might result in mutations that are not corrected or removed, resulting in early senescence or illness. Larger breeds may be subjected to higher levels of oxidative damage for longer periods of time during development from puppy to adult, resulting in an increased incidence of illnesses linked to free radical damage and, as a result, early death (Jimenez, 2016).

Certain giant breeds have excessive loose skin and skin folds, e.g.the St. Bernard. This can cause the eye conditions entropion and ectropion, where the eyelids curve inward and outward respectively. Both can co-occur and cause a “diamond – shape” of the eyes, where the corners are entropic and central lower lid ectropion (Asher et al., 2009).

3.1.2 Toy conformation

Odontoid process dysplasia, shoulder dysplasia, and patellar luxation are all conditions linked to small body size, particularly those with shorter legs (Asher et al., 2009). The odontoid process or the “dens” is a peg-like projection from the second cervical vertebrae (axis), connecting the atlantoaxial joint. It is important for proper rotation of the head and

neck. In the case of odontoid process dysplasia, the dens can be too small or even missing, causing painful spinal cord compression which can lead to paralysis or death. Shoulder dysplasia is when the shoulder joint is incongruent, which can result in lameness and osteoarthritis. Patellar luxation is a condition where the patella or kneecap “jumps out from its groove” and causes lameness. It is said to be most common in Terrier and toy breeds. According to the Orthopaedic Foundation for Animals (OFA), the Yorkshire terrier has a prevalence rate of 15% and the Shar-Pei has a prevalence rate of 13.8%. Because luxation often is a transitory condition (may only occur during exercise), it may go unnoticed (Asher et al., 2009).

In toy breeds, inadequate cartilage ring formation might result in trachea collapse (Rooney & Sargan, 2010). It is especially a prevalent problem in older dogs. The pathomechanism is a tracheal structural anomaly characterized by a variable degree of tracheal ring dorsoventral flattening and flaccidity (Pardali et al., 2010).

Chihuahuas—even in adulthood, frequently have open fontanelles or cranial vault bones that do not fuse. These open fontanelles are most likely linked to these dogs' exceptional dwarfism and correspondingly enormous brain size, as the bones of the cranium become sparse (Geiger et al., 2021). Persistent fontanelles can be linked to disorders like Chiari-like malformation and syringomyelia (Kiviranta et al., 2021)

3.1.3 Brachycephalic conformation

Skull shape can be divided into doliocephaly, mesocephaly, and brachycephaly. Doliocephaly describes an elongated muzzle to a narrow skull. Found in breeds like Shetland sheepdog and whippet. Mesocephaly describes an ideal/intermediate muzzle to skull ratio, seen in the Siberian husky or golden retriever. Brachycephaly describes a shortened muzzle to skull ratio and is seen in breeds like pug and bulldogs (see Figure 1.).

Figure 1: ***Skull shape of specific breeds****. (A) Shetland sheepdog (dolichocephalic); (B) Labrador, (C) Bulldog (brachycephalic), (D) French bulldog (brachycephalic)* (Ekenstedt et al., 2020)

The skull has been selected to be reduced from front to back in brachycephalic breeds. This can restrict the flow of air through the nose, and together with a comparatively elongated soft palate can create problems, such as breathing difficulties, and the inability to lead an active life without respiratory distress. A quantitative analysis showed that brachycephalic and gigantic breeds suffer from increased mortality compared to other breeds (Rooney & Sargan, 2010) Brachycephalic breeds will be further discussed in later paragraphs.

3.1.4 Chondrodystrophic conformation

Chondrodystrophic breeds, selected for disproportionally short legs, have an increased prevalence of IVDD (intervertebral disc degeneration) (Smolders et al., 2013). IVDD is characterized by an abnormal cartilage growth (chondroid metaplasia) in the nucleus pulposus (Asher et al., 2009) The intervertebral discs consist of the hard outer annulus fibrosus and the soft inner core of the nucleus pulposus.

Typical breeds include dachshund, corgi, basset, and Tibetan spaniel among others. IVDD is usually seen between 3-7 years of age and affects the cervical or thoracolumbar part of the spine. In these breeds, IVDD typically progresses quickly, and dorsal herniation of the nucleus pulposus can occur as early as 2 years of age. It often occurs acutely, with complete herniation and rupture of dorsolateral or dorsomedial annulus fibrosus. This type I Hansen herniation is more common in chondrodystrophic breeds than others. Type II Hansen herniation is also seen but to a lesser degree. It is non-complete herniation and disorganization of the annulus fibrosus (as seen in Figure 2) (Smolders et al., 2013)

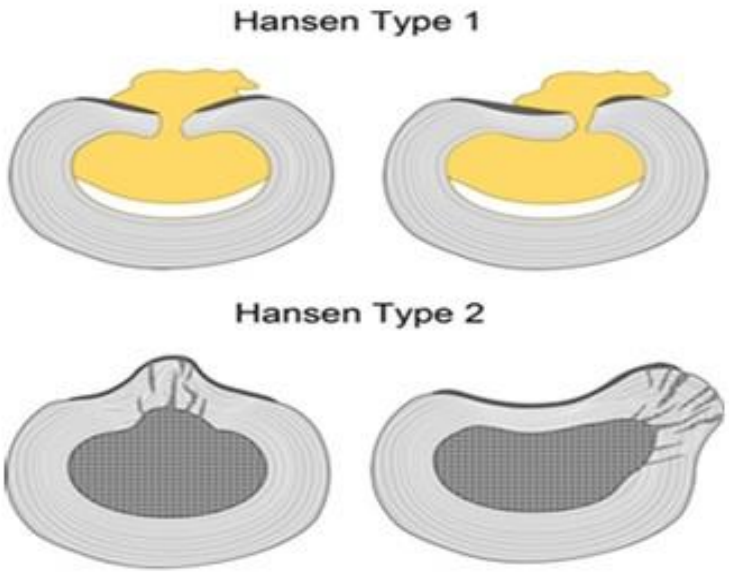

Figure 2: ***Herniation types.*** *Type 1 IVD herniation is the complete rupture of dorsomedial (upper left) or dorsolateral (upper right) annulus fibrosus (grey), dorsal longitudinal ligament (dark grey), and degenerated nucleus pulposus (yellow). Type 2 is the partial rupture and disorganization of the annulus fibrosus and bulging of nucleus pulposus and dorsal longitudinal ligament dorsomedial (lower left) or dorsolateral (lower left)* (Smolders et al., 2013).

Although not necessarily a health issue, Dachshunds have been shown to have increased concentrations of red blood cells. A study showed that Dachshunds have higher PCVs and HCT than mixed breed dogs. According to some sources, the increase in PCV, HCT, RBC, and HGB concentrations could be related to splenic constriction, caused by stress. Nervous breeds, such as Dachshunds, could experience a surge of excitement, a lack of oxygen in the tissues, or an increased secretion of erythropoietin. Another study theorized that Dachshunds are a small chondrodystrophic breed that was originally bred to be "badger hounds" and therefore adapted to hunting underground, where oxygen concentrations may be lower. Therefore, a higher concentration of oxygen-carrying red blood cells may have been selected for (Torres et al., 2014).

3.2 Non-conformational related disorders

Breeding in dogs not bred to the extreme in looks also shows decreased health in many instances because of the tendency to use a narrow gene pool. The goal has been to achieve a certain look and the health has come second. The narrow gene pool has been accomplished with inbreeding. Inherited illnesses, as metabolic problems, neurological and sensory

disorders, immune system abnormalities, blood disorders, and congenital physical deformities have long been recorded in veterinary literature (Summers et al., 2010).

The inheritance of genetic diseases can be controlled by a single gene (monogenic conditions) or several genes (polygenic conditions). There are four types of single gene inheritance: autosomal dominant/recessive and X-linked dominant/recessive. Autosomal recessive usually presents with disease if two copies of the recessive allele are present on a non-sex chromosome. Autosomal dominant diseases will present if only a single copy is present. Polygenic disorders are inherited by several genes and are often influenced by environmental factors as well. The homogeneity of pedigree breeds caused by inbreeding can contribute to the inheritance of recessive gene alleles which increase the prevalence of certain disorders. In a study, German shepherd dogs were susceptible to the most inherited diseases, followed by the Golden retriever, Boxer, Labrador retriever, and English Springer spaniel, among the UK's 50 most popular purebred dogs (Summers et al., 2010).

3.3 Generic illness severity index for dogs

This index was generated after the documentary *pedigree dogs exposed*. GISID attempts to numerically value prognosis, therapy, complications, and how the disease impacts behavior to arrive at a disease-specific overall score ranging from zero to sixteen for each condition. When this information is combined with estimates of prevalence and disease duration, a welfare-index, ranging from zero to 16 may be generated for each disorder at the population level, with higher values indicating a more severe impact on the dog's welfare (as seen in Figure 3) (Broeckx, 2020)

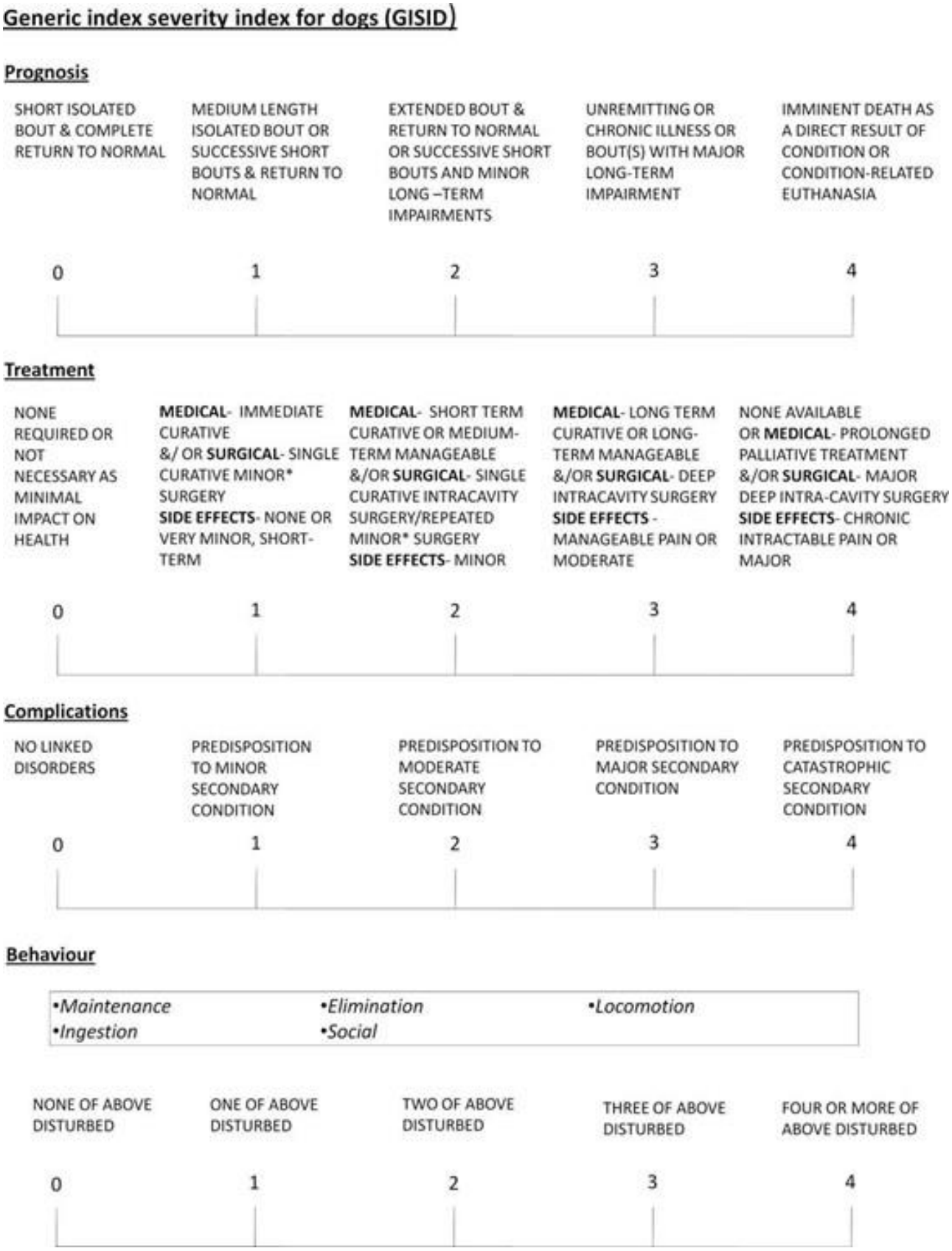

Figure 3. ***The generic illness severity index for dogs****. Each point has a score from 0 to 4, where 0 is the least serious and 4 is the most serious. Added together is the minimum possible score 0 and maximum possible score 16 for each disorder* (Asher et al., 2009)

4. Brachycephalic Anatomy

4.1 Skull

There have been several systems suggested for the categorization of brachycephalic individuals, where different indices of skull, neurocranial and facial width and length in both living and dead specimens are proposed. Today there isn't t any complete list of brachycephalic breeds since different individuals within a breed can show either brachycephaly or non-brachycephaly. One categorization system which is proposed is the angle between the base of the cranium and the pars facialis of the skull. Airorhynchy describes a dorsal rotation of the snout from the palate. This causes an angle that is greater than 180 degrees between the cranial base and palate (Geiger et al., 2021). However, brachycephaly is commonly described as a shortened muzzle and a widening of the skull compared to the mesocephalic dog. These include the breeds like pug, English bulldog, and French bulldog among others. The sinuses are often absent or reduced, and the nasal turbinates are oversized and extend into the nasopharynx of the dog (Ekenstedt et al., 2020). The ocular orbits are more shallow, leading to less space for the normal-sized eyeballs (Geiger et al., 2021). They are often affected by mandibular prognathism or underbite (Ekenstedt et al., 2020) The premature closure (synchondrosis) of the centers of endochondral ossification inside the basisphenoid and basioccipital bones is considered to be the cause of basicranial shortening. Compensatory changes in other cranial bones, such as broadening, may occur when the basicranial axis shortens and lead to neural congestion (Fawcett et al., 2019).

Although brachycephaly is most noticeable in the facial part of the cranium and the mandible, it can also be linked to changes in the shape of the vertebrae, scapula, pelvis, and the long bones of the limbs. Most of these bones are more compact in brachycephalic breeds than in non-brachycephalic breeds (as seen in Figure 4). Processes of development and genetics in brachycephaly, therefore, have an impact on not only the skull but the rest of the skeleton as well (Geiger et al., 2021).

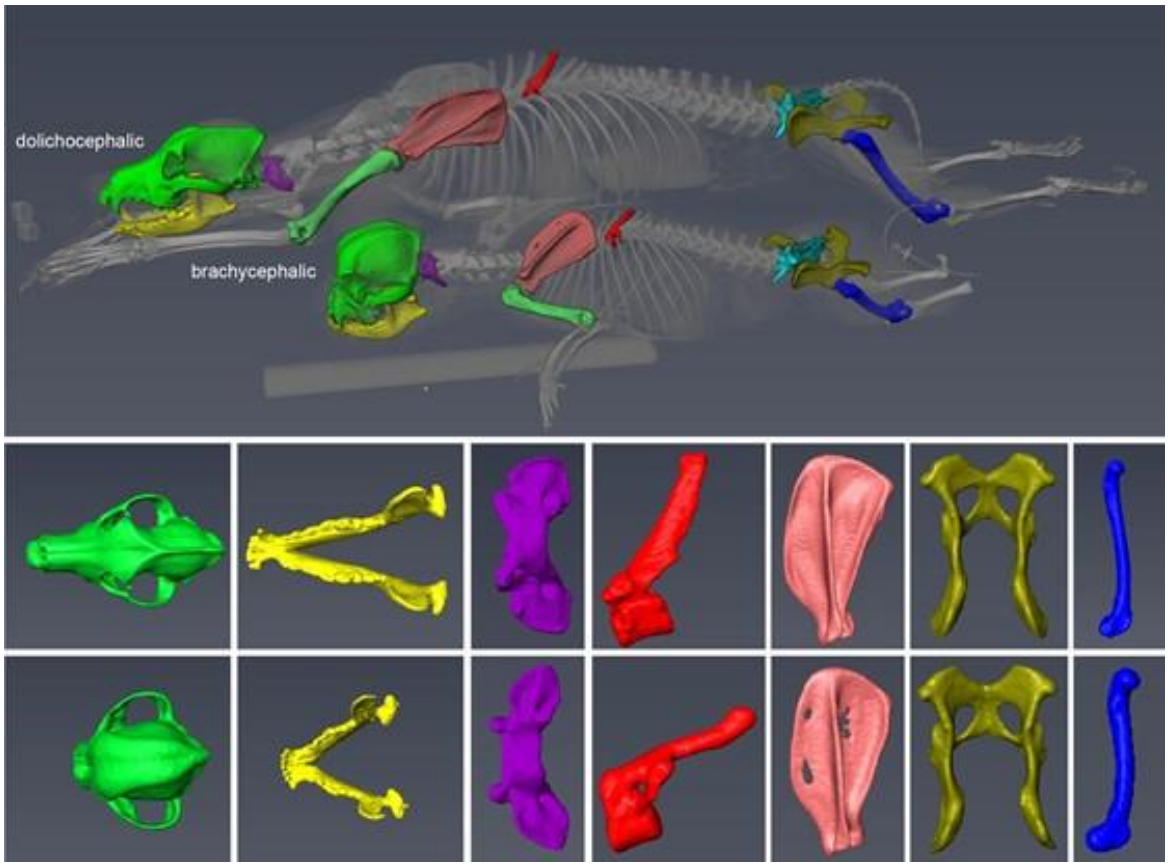

Figure 4. ***Brachycephaly and its correlation with the rest of the skeleton****. Brachycephaly is mostly concerned with craniofacial changes as seen in the cranium (green) and mandible (yellow), but it may also affect the shapes of the vertebras, such as the atlas (purple), thoracic vertebrae (red), scapula (pink), pelvis (olive) and femur (blue)* (Geiger et al., 2021)

4.2 Vertebral column

Since many breeds of brachycephalic conformation are selected for a short, absent, or screw-tailed look, congenital malformations of the vertebral column are a prevalent finding. In French Bulldog, English Bulldog, and Pugs it is often found accidentally. Some malformations are hemivertebrae, block vertebrae, and defects like spina bifida and transitional vertebrae (Ryan et al., 2017).

Hemivertebrae describes a vertebral anomaly that results from the lack of one half of the vertebral body. It may be presented with or without congenital scoliosis, which is the lateral curvature of the spine. In a study, hemivertebrae were present in 90% of subclinical French bulldogs (Ryan et al., 2017). In a block vertebra, there is a partial or complete fusion of adjacent vertebral bodies. Spina bifida is a type of neural tube defect, and can happen anywhere along the spine if the neural tube does not close properly, leading to exposure of

the spinal cord. A transitional vertebra has undetermined characteristics and features of vertebrae from adjacent vertebral segments. They occur at the junction between spinal morphological segments. Can either be an extra bone or a “hybrid” bone.

The malformations are often found in the thoracic vertebrae, and one or more segments can be affected. Although they have the potential to cause severe clinical signs, it is shown that they more often do not. 78% of neurologically normal French Bulldogs showed hemivertebrae during radiography, some of these included kyphoses, which is an upward curvature of the spine (Ryan et al., 2017).

4.3 Soft tissue

These skeletal changes also affect the soft tissue. Especially the nasal and pharyngeal airways, which get compressed. The soft tissues of the upper respiratory tract, as nostrils, mucosa, soft palate, tonsils, and tongue, are not reduced proportionately with the facial skeletal reduction (Ekenstedt et al., 2020). Especially French bulldog, Bulldog, and pug have been identified with macroglossia (Siedenburg & Dupré, 2021). These changes lead to incongruous dimensions and a narrower lumen in the upper respiratory tract due to a relative excess of soft tissue obstructing the airflow (Ekenstedt et al., 2020) From the cranial base, the oropharynx, larynx, and hyoid are suspended. Shortening of the skull base may shift these tissues as well, and the tongue, impacting swallowing and respiration caudally (Rusbridge & Knowler, 2021).

BOAS is a disorder characterized by primarily anatomical anomalies. These include stenotic nares, an extended soft palate, and a hypoplastic trachea, producing airflow resistance and difficulties breathing. As a result, negative intraluminal pressure rises during inspiration. This can in serious cases lead to everted laryngeal saccules, pharyngeal hypertrophy, tonsillar hyperplasia, and ultimately laryngeal collapse. The collapse of the larynx has been observed in dogs as early as 4.5 months of age (Fawcett et al., 2019) Histopathology of the thickened soft palate in BOAS-affected dogs has shown a significant increase in muscle degeneration and necrosis, both in acute and chronic muscle degeneration. The thickening of palatal tissue in BOAS-affected canines was not caused by muscle hypertrophy or fat deposition, according to researchers, but by increased stroma in the lamina propria, edema, and increased salivary tissue. It was shown that brachycephalic dogs had decreased amount

of muscle tissue. The muscle necrosis is thought to be because of repeated trauma by overuse and hypoxia, and edema secondary to the turbulent airflow or by gastric reflux into the laryngopharynx. The increased concentration of salivary tissue is theorized to be because of nasopharyngeal obstruction which may cause the caudal part of the oral cavity to dry out, and therefore an increase in salivary tissue to compensate (Ekenstedt et al., 2020)

5. Brachycephalic physiology

The anatomical changes seen in these breeds also affect the dog's physiology, as they have increased difficulties with breathing and thermoregulation, but also changes in digestion and their cardiovascular system, which is affected by their conformation.

5.1 Respiratory system

The respiratory tract is the most prevalent place for clinical manifestation of BOAS, with symptoms including exercise and heat intolerance, frequent sleep disturbance, and syncope, which can be life-threatening (Freiche & German, 2021). With a narrower tracheal lumen, the airflow becomes turbulent. This may lead to reduced clearance of carbon dioxide and subsequent respiratory acidosis. This along with hypoxia and hypertension is thought to cause oxidative stress and changes in homeostasis which can explain the decreased lifespan some of these extreme brachycephalic dogs have. The median lifespan of extreme brachycephalic is 8,6 years, as opposed to non-brachycephalic which is 12,7 years (Fawcett et al., 2019). Breathing patterns in brachycephalic dogs are comparable to those seen in humans with obstructive sleep apnea syndrome. Dyslipidemia, hyperglycemia, and insulin resistance are all linked to obstructive sleep apnea syndrome. Even though brachycephalic morphological and functional changes are widely documented, the effects of upper airway constriction on systemic inflammatory response and metabolic changes in dogs aren't as fully understood. It is suggested that intermittent hypoxia is thought to cause excessive lipolysis, which supplies free fatty acids to the liver, as well as elevation of hepatic triglyceride production, lipoprotein secretion, and suppression of lipoprotein clearance. All of this can contribute to dyslipidemia. Insulin resistance can be induced by a variety of factors as stimulation of hepatic lipid production, sympathetic nervous system activation with resulting lipolysis, hypothalamic-hypophyseal-adrenal axis activation, and systemic inflammation (Gianella et al., 2019)

In a study, clinically healthy brachycephalic dogs had substantially lower SpO2 values than meso-, and doliocephalic dogs, although all dogs had SpO2 levels within the normal range of 95–100%. Even though these results were statistically significant, the clinical significance may be found in noticing a change in SpO2 measurement for the individual dog. Hypoxemia should not be accepted as normal for any breed (Arulpagasam et al., 2018).

During periods of heat stress, brachycephalic dogs are less capable of thermoregulating than non-brachycephalic dogs, with a much higher increase in respiratory rate when ambient temperatures rise, compared to healthy non-brachycephalic dogs (Fawcett et al., 2019)

5.2 Cardiovascular system

Dogs with brachycephalic facial conformation tend to have a greater risk of cardiovascular illness than dogs with meso-, and doliocephalic conformation (Crane et al., 2017). Negative intraluminal pressure caused by turbulent respiration also reduces venous return to the heart, and increases the risk of cerebral venous hypertension, and decreases CSF drainage which may lead to neurological symptoms (Rusbridge & Knowler, 2021).

In seriously afflicted BOAS dogs, researchers have discovered significant hypercoagulability and delayed fibrinolysis. TEG (thromboelastography) alterations in seemingly healthy Bulldogs were also seen in a 2015 research, although the changes were less notable (Crane et al., 2017). TEG is a non-invasive test that measures the clot-forming ability of the blood. It can both detect hypocoagulability and hypercoagulability. Although the BOAS grade system was not used in the research, it did include Bulldogs that were clinically healthy. At rest, there was no audible noise during inspiration or dyspnea. These findings suggest the existence of a hypercoagulable condition in brachycephalic dogs, which may increase as the severity of BOAS increases (Crane et al., 2017).

In a study, the BOAS-afflicted dogs had a higher hematocrit than the mesocephalic control dogs. It's unclear if this was due to persistent hypoxia or just relative polycythemia caused by the loss of bodily fluids through respiration. There have also been reports of higher hematocrits in healthy Bulldogs than other canines (Crane et al., 2017).

5.3 Digestive system

Most prior studies have focused on the respiratory effects of BOAS, although many of the dogs also exhibit symptoms of the digestive tract, such as ptyalism or drooling, frequent swallowing attempts, regurgitation, eructation, vomiting, and appetite abnormalities. The severity of digestive signs closely correlates with respiratory signs (Freiche & German, 2021).

It is thought that the negative intraluminal pressure in the upper airways in addition to causing secondary respiratory signs also causes digestive tract lesions like gastroesophageal reflux and diaphragmatic hernia. In brachycephalic dogs, studies of video fluoroscopic swallowing have revealed esophageal dysmotility, as well as a longer esophageal transit time and gastroesophageal reflux (Freiche & German, 2021). Excessive flatulence because of aerophagia is common as well. The digestive signs in French Bulldogs are more frequent and severe than in other breeds (Gianella et al., 2019).

6. Welfare in brachycephalic dogs

Some popular breeds which are considered brachycephalic are the English bulldog, French bulldog, Pug, Boston terrier, Shih Tzu, Cavalier King Charles, Pekingese, Boxer, Dogue de Bordeaux, and Bullmastiff. There are differences between each breed, as size and body conformation, and grade of brachycephaly. In studies, it is often the Pug, French bulldog, and English bulldog that's chosen as subjects for research, as they are deemed more on the extreme end of brachycephaly. An Australian insurance company: Petsure, shows that there has been an increase in the popularity of these three breeds over the last couple of years. They also show that there has been a 69% rise in BOAS-requested surgeries between 2013 and 2017. Recent research using computed tomography (CT) for examination of airway dimensions, showed that Pugs are notably affected by the skull abnormalities, with dorsal rotation of the maxillary bone, while French bulldogs had more severe soft tissue changes, particularly the thickening of the soft palate (Fawcett et al., 2019) When compared to mesocephalic and dolichocephalic breeds of equal body size, the average lifetime of brachycephalic breeds is about three years shorter (Packer, Hendricks, Tivers, et al., 2015).

The five freedoms are internationally accepted standards of animal welfare that apply to all animals under human care. These are *"freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury, or disease, freedom to express normal behavior, and freedom from fear and distress*". This is stated in the Farm Animal Welfare Council (1992) (Bovenkerk & Nijland, 2017) Many breeds are born with a high risk of being denied at least one, if not more, of the five freedoms. Anatomies that are exaggerated suggest that dogs may experience discomfort and are unable to behave normally. With an increased risk of trauma and contracting illnesses which can result in discomfort, fear, and agony (Rooney & Sargan, 2010). The welfare of these dogs with the artificially selected head shape has long been in focus. Several sequelae can be explained by this exaggerated phenotype.

6.1 BOAS

BOAS is linked to a wide variety of clinical symptoms, and it may affect all brachycephalic dogs to some extent (Crane et al., 2017). In the worst cases it can cause cyanosis, syncope, or even death (Liu, Troconis, et al., 2017) Individuals who are severely affected have labored breathing and frequently takes a wide posture with their elbows abducted from their chest,

as well as the use of additional abdominal musculature (Packer, Hendricks, Tivers, et al., 2015).

The condition is one that worsens with time. The age of presentation varies from a few months to a few years; however, BOAS is uncommon to appear in dogs older than 5 years of age for the first time. A systematic method is required for a reliable diagnosis. includes a comprehensive clinicopathologic study, a history, and a physical examination endoscopy to check both the upper and lower airways, and diagnostic imaging of the gastrointestinal tract (Freiche & German, 2021) Tidal breathing flow-volume loop, and whole-body barometric plethysmography are all currently utilized to diagnose the clinical manifestations of BOAS, these are non-invasive diagnostic tests. Quantitative data on airflow characteristics in the upper airway of dogs, particularly brachycephalic breeds, is hardly recorded. This is because of the invasive nature of using measuring devices and narrow nasal passages which are made more complicated by complex sinuses (Khoa et al., 2021).

For grading of BOAS, there exists a 4-point grading system, based on clinical examination before and after an exercise-tolerance test. The exercise-tolerance test is done by a 3-minute trot at a speed of 3-8 km/h. Grade 0, Grade I, Grade II, and Grade III describes asymptomatic (BOAS free), mild respiratory noise (mild BOAS), in need of medical attention (moderate BOAS), and in need of surgery (severe BOAS) respectively (Liu, Troconis, et al., 2017).

Turbulent airflow and chronically high negative pressures in the pharynx cause laryngeal collapse. The degree of laryngeal collapse is categorized into three stages: Stage 1, Stage 2, and Stage 3. For stage 1 everted laryngeal saccules are typical. Stage 2 includes displacement of the cuneiform process medially. For stage 3, the corniculate process of the arytenoid cartilage collapse (Fawcett et al., 2019). This is the most prevalent and serious secondary alteration. It has a grave prognosis in the late stages (Packer, Hendricks, Tivers, et al., 2015). Bronchial collapse, a less mentioned effect of BOAS is strongly related to that of laryngeal collapse. Pugs have been shown to be the most commonly and seriously afflicted (Siedenburg & Dupré, 2021)

Dogs with stenotic nostrils can have poor temperature regulation and an abnormal rise in negative pressure within the airway due to the limitation of airflow at the airway's entry. In a study, 45 % of French bulldogs showed significant stenosis of the nostrils, which is a common problem in the breed (Liu, Troconis, et al., 2017). Poor temperature regulation causes exercise intolerance as the body cannot properly cool itself. In a study, 88% of

brachycephalic owners said that their dogs were exercise-intolerant, with 70% of those afflicted being primarily during the summer. During summer, 33% of the dogs could only walk for 10 minutes. During winter, 77% could walk at least 30 min. The recovery time was longer than in the summer than winter, with about 50% of the dogs needing 30 min to recover during summertime (Roedler et al., 2013).

Obesity has been shown as a risk factor for BOAS in previous studies. Obesity affects respiratory function by reducing minute volume while increasing respiratory rate, causing exercise intolerance, and lowering estimated arterial oxygen saturation (Liu, Troconis, et al., 2017). In addition to obesity, increased absolute neck girts severely increase the risk of clinical BOAS (Packer, Hendricks, Tivers, et al., 2015).

6.1.1 Tidal breathing flow-volume loop

In human medicine, pulmonary function tests are commonly used to aid in the diagnosis and treatment of respiratory illnesses. The acquirement of a maximum expiratory and inspiratory volume is one of the most common tests, but this is difficult in animals as it demands cooperation. However, during the last 20 years, the tidal breathing flow-volume loop (TBFVL) has been in use. Tidal breathing flow-volume loops are a graphic representation of airflow rate vs tidal volume for each breath. Originally made for use in infants. It is a quick, noninvasive, and simple diagnostic tool (Pardali et al., 2010).

6.1.2 Whole-body barometric plethysmography

Whole-body barometric plethysmography (WBBP) is a non-invasive approach for assessing the respiratory function that has been validated and used to characterize respiratory patterns during sleep and wakefulness in unrestrained non-sedated experimental mice. This technique has also been employed in pharmacological research and respiratory problems utilizing dogs and cats in experimental and clinical studies (Liu et al., 2016). WBBP measurements are generated with the help of a barometric chamber. Different sizes exist for small and medium-sized breeds, with 175 L and 280 L inner volume respectively (Liu, Oechtering, et al., 2017)

After clinical assessment, the dog is placed in the chamber. Respiratory function is then noted over the next 20 min after a period of acclimatization of around 10 minutes. Artifacts

that come from moving, vocalization, and sniffing should be identified and removed manually from the time recording. Ratios of peak expiratory and inspiratory flowrate, time, and volume/minute/kg BW is then used as means and standard deviations (Liu, Oechtering, et al., 2017)

6.1.3 Surgical correction

Early identification of BOAS is advantageous because surgical treatments to improve airflow can prevent secondary alterations from progressing. Visualization is a simple way to diagnose stenotic nares. Endoscopy is frequently used to examine the pharyngeal and laryngeal tissues. It's better to use general anesthesia for this procedure, and since anesthesia is a high-risk procedure in BOAS dogs, such procedures are often done together with surgery (Ekenstedt et al., 2020).

The surgery requires that the patient is lying in sternal recumbency (Fawcett et al., 2019). Alaplasty, or vertical wedge resection of the ala nasi, staphylectomy, where the caudal part of the soft palate is removed, partial tonsillectomy, and laryngeal ventriculectomy, which is the surgical resection of everted saccules are the most common surgical methods used to treat the anatomical defects that contribute to BOAS. Modified and advanced procedures such as folded flap palatoplasty (FFP), nasal vestibuloplasty, and laser-assisted turbinectomy (LATE) have recently been done (Liu, Oechtering, et al., 2017). FFP shortens and thins the soft palate, while nasal vestibuloplasty addresses the vestibule of the nasal wing as well, and LATE removes obstruction in medial and ventral nasal turbinates.

Rhinoplasty is required for severe stenosis to increase the external nostril's accessibility to air; nevertheless, the specific improvement from surgery in terms of respiratory physiology and inhaled air intake has not been thoroughly explored. By eliminating the nasal wing and wing fold tissue, rhinoplasty expands the nose opening region. Because of the effective control of bleeding and the relatively decent appearance of the surgical wounds, wedge shape excision of the external nose with suture has recently become the standard surgery approach. However, no quantitative research has been done to confirm the efficiency after this procedure (Khoa et al., 2021)

Surgeries can be divided into TMS (traditional multilevel surgery and MMS (modified multilevel surgery). In TMS (traditional multilevel surgery), alaplasty, staphylectomy,

laryngeal ventriculectomy, and tonsillectomy are traditionally done. In MMS (modified multilevel surgery), a modified technique in rhinoplasty is used, combining a special alaplasty and nasal vestibuloplasty form. The nasal wing is resected dorsomedial and caudally, which widens the nasal vestibule. The stenosis is expanded both externally and internally. The ventriculectomy is done by using endoscopic scissors. MMS consists of a combination of recently introduced surgical techniques that improve nasal flow by several procedures: partial resection of the alar folds in the nasal vestibule, removing thickened hypertrophic tissue of the soft palate, and trimming the malformed cuneiform process, which may cause laryngeal collapse. The effects of all these surgeries show promising results (Liu, Oechtering, et al., 2017)

6.1.4 Prognosis

With surgery, over 90% of BOAS dogs have a considerable improvement in their respiratory function, but despite proper surgical therapy, it is shown that 60 percent of dogs' respiratory function remains impaired (Fawcett et al., 2019) Key prognostic factors for BOAS surgery are age, body condition, and laryngeal collapse. Better prognosis is seen with lower age, lower body condition score, and the absence of laryngeal collapse. MMS may produce better results than TMS (Liu, Oechtering, et al., 2017).

6.2 Digestive issues

The main digestive tract issues that affect brachycephalic dogs are vomiting and regurgitation. Chronic enteropathy is also often seen in brachycephalic dogs and protein-losing enteropathy is especially seen in pugs. Gastroesophageal reflux, sliding hiatal hernia, delayed gastric emptying, gastritis, pyloric fold hypertrophy, stenosis, and duodenitis are also seen more prevalent in these breeds (Freiche & German, 2021) Gagging, regurgitation, and vomiting are clinical symptoms of gastrointestinal lesions that can be caused by prolonged negative pressure in the chest cavity (Packer, Hendricks, Tivers, et al., 2015)

6.3 Odontology

Dental issues such as malocclusion, rotation of premolars, and severe crowding of teeth are caused by the changed facial skeletal structure, especially the reduced maxillary bone, which still contains a normal number of teeth crammed into a considerably smaller area (Ekenstedt et al., 2020). This may impair the dog's ability to chew and have implications for stress reduction, as chewing is theorized to be a key canine-stress coping strategy (Fawcett et al., 2019). The firm hard palate can have deeper folds, which causes the food and hair to become trapped, causing palatitis and persistent ulcers. Dental disease is difficult to prevent and brushing the teeth of these canines is tough due to the need for their mouths to breathe. Cleaning each tooth is more difficult due to dental crowding. Dental extractions are often needed to relieve these issues (Ekenstedt et al., 2020).

6.4 Ophthalmology

Brachycephalic face conformation can result in lagophthalmos (inability to completely shut the eyelids) (Fawcett et al., 2019). Extra-large palpebral fissures (eyelid apertures) and/or extremely shallow orbits are thought to be the cause of exposure of the white area of the eye. (Packer, Hendricks, & Burn, 2015). Comparatively large palpebral fissures are common in these breeds. Large palpebral fissures are usually associated with shallow orbits in these dogs, resulting in unnaturally projecting eyes that are vulnerable to external injuries. Corrective surgery (medial canthoplasty) is frequently used to reduce lagophthalmic problems and the risk of globe prolapse by shortening the big palpebral fissure by 6–8mm (Packer, Hendricks, & Burn, 2015) The inability to completely shut the eyes predisposes afflicted dogs to corneal ulceration, a painful eye condition that can lead to scarring, corneal perforation, or permanent blindness. In a study of several dogs of different breeds, the pug was the one most affected by corneal ulcers (Fawcett et al., 2019). In another study, dogs with nasal folds were roughly five times more likely than those without to develop corneal ulcers, while brachycephalic dogs were twenty times more likely than non-brachycephalic dogs to develop ulcers. Damage to the cornea is thought to generate significant pain since it is innervated by nerves (Packer, Hendricks, & Burn, 2015). Trichiasis or misdirected eyelashes, is a greater risk in these eyes, due to hairs on the nasal skin fold near the medial canthus. These diseases can lead to blindness or possibly the loss of an eye (Ekenstedt et al.,

2020). Entropion and ectropion are also seen in high prevalence in Pugs and Bulldogs, which are inverted and extraverted eyelids respectively (Asher et al., 2009).

6.5 Reproductive issues

Brachycephalic breeds are prone to reproductive problems, most notably dystocia. In the United Kingdom, cesarean sections are used to birth almost 85% of bulldog puppies. This is because the heads of the dogs are too big to pass through the vaginal canal (Ekenstedt et al., 2020). Studies have also shown that the pelvis is both smaller, narrower, and shorter compared to non-brachycephalic (Dobak et al., 2018).

6.6 Dermatological issues

Since the maxillary bone is reduced, it results in redundant skin, excessive folding on the nose ridge, and subsequent dermatitis (Geiger et al., 2021). The skin over the short muzzle is not reduced in proportion to the facial bones in several brachycephalic breeds, resulting in wrinkles. The fold, or hairs that sprout from the nasal fold, can rub the cornea of the eye, resulting in painful traumatic keratitis and ulceration. Nasal fold trichiasis is the medical word for this condition. In serious cases, this may need surgical resection (Packer, Hendricks, & Burn, 2015). These deep skin folds can lead to rash, as chafing and moisture cause trauma and inflammation. Brachycephalic dog breeds have a long history of dermatological problems, such as face and tail fold intertrigo, pattern baldness, and atopic dermatitis. Mast cell tumors, muzzle/pedal folliculitis, dermatitis, demodicosis, Malassezia dermatitis, and furunculosis are also seen more prevalent. In English bulldog flank alopecia and Cavalier King Charles spaniel, secretory otitis media are breed-specific disorders (Fawcett et al., 2019).

A study of English Bulldogs was done to originally identify healthy individuals without any signs of dermatitis or gastrointestinal diseases and compare them to diseased individuals. 34 dogs at two dog shows were evaluated. However, all the dogs had clinical signs or history of pruritus and over half of the dogs had been medicated for dermatological conditions recently. The study could not be concluded since they could not find any dogs free from gastrointestinal or dermatological disorders. The high prevalence of inbreeding to get and

maintain the desired look has not only caused physical discomfort caused by conformation but also affected the genes that regulate the normal immune response (Fawcett et al., 2019)

6.7 Neurological disorders

Syringomyelia (SM) is the most prevalent neurologic disease in dogs with brachycephaly, and it is usually accompanied by a Chiari-like deformity of the skull. Syringomyelia is an accumulation of fluid within the spinal cord. It may occur segmentally in the spinal cord or extend through the entire length. Syringomyelia in the cervical region or the neck is often seen in brachycephalic dogs. Chiari-like malformation is a herniation of the cerebellum and medulla oblongata into the foramen magnum. The cause is thought to be multifactorial, with an increased cerebellar volume and decreased fit of the caudal cranial fossa. It is most often described in Cavalier King Charles Spaniel and is reported to occur in 100% of individuals of this breed (Fawcett et al., 2019) The malformation is linked to the selection of skulls that are steep caudally and is assumed to be painful and cause severe brain damage (Asher et al., 2009). The mechanism that causes the pain is a subject of debate. The most plausible mechanism is obstruction of cerebrospinal fluid channels and lower intracranial compliance causing increased intracranial pressure (Rusbridge & Knowler, 2021).

Other cerebrospinal fluid (CSF) circulation abnormalities in brachycephalic dogs and cats include hydrocephalus and ventriculomegaly. Hydrocephalus refers to active distension of the brain's ventricular system caused by insufficient CSF passage from the point of production inside the cerebral ventricles to the point of absorption into the systemic circulation. Ventriculomegaly is the term used to describe ventricular distension in otherwise healthy animals. Animals with hydrocephalus, on the other hand, are neurologically abnormal, with forebrain illness and a variety of symptoms like cerebello-vestibular symptoms and head or cervical pain (Rusbridge & Knowler, 2021).

Because the bulk of CSF is absorbed by lymphatics in the skull base and via the olfactory bulbs, craniofacial hypoplasia and cranial base shortening may affect the equilibrium between CSF production and absorption. CSF mobility is also inhibited by apnea, as CSF outflow through the venous sinuses is hampered by apnea-induced negative intrathoracic pressure. This has clear consequences for brachycephalic dogs with BOAS, particularly if they suffer from sleep-disordered breathing. During sleep, intracranial pressure rises, and

disrupted sleep affects glymphatic drainage, which is more active at night (Rusbridge & Knowler, 2021). The glymphatic system is a macroscopic waste clearance system that uses a unique system of perivascular channels generated by astroglia cells to enable efficient removal of soluble proteins and metabolites from the central nervous system (Jessen et al., 2015).

7. The future of selective breeding

The brachycephalic conformation was probably chosen for its possible combat advantage, based on the notion that this cranial conformation resulted in greater biting force. The first dogs of these breeds were used for bull fighting in England in the 1200s and until the mid-1800s in Europe (Ekenstedt et al., 2020). The skull shape has gradually decreased in facial length while increasing in skull width proportionally during the last century, and it has been claimed that this is linked to an increase in BOAS severity and prevalence (Liu, Troconis, et al., 2017). BOAS has been recognized as a condition for a long time, with surgical treatments established to treat it as early as the 1940s (Packer, Hendricks, Tivers, et al., 2015). Today, their role has shifted to that of a companion animal with a look that's appealing to a certain part of the public. Their popularity has been attributed to that of the paedomorphic look which is thought to trigger the same attraction and nurture response in adults that are caused by a human baby (Ekenstedt et al., 2020).

It has been suggested that for the well-being of future generations, the breeds that have the poorest health should be abandoned. At the same time, interbreeding between the remaining breeds should be done to increase genetic variation. This would mean that many breeds would go extinct and the breeds we know today would lose their strict characteristics. Another solution that may be more feasible is to cross closely related breeds to get more genetic diversity again. Insurance companies also know the higher health risk certain breeds have. When owners ensure their dogs, insurance companies keep track of how often and for what reason owners with different breeds use their policies. This information is used to calculate premiums. For many dog owners, ensuring a pedigree dog may mean paying much higher premiums than insuring a crossbreed (Farrell et al., 2015).

"Designer dogs" are a relatively new trend where purebreds are crossed with other purebreds to create a hybrid. These are increasingly popular among the public. Poodle is a breed that is used often to make crosses like Labradoodle (Labrador Retriever and Standard Poodle) and Cockerpoo (Cocker spaniel and Miniature poodle). There have been attempts to fix the characteristics of these into a purebred breeding line and register them as their own breeds. This outcrossing increases the genetic diversity but doesn't necessarily mean that the dogs are healthier. Labrador retriever and Standard poodle are both susceptible to several of the same inherited disorders. In these cases, it's important to choose healthy lineages with maximum genetic variability. Unfortunately, creating new breeds based on appearances may

not be the way to go to better canine welfare, given our history with selective breeding (Farrell et al., 2015). Designer breeds are often bred by people purely for profit, and the necessary health testing isn't done. This may cause puppies to be born with more health issues than their purebred counterparts, even though in theory the genetic diversity will increase.

7.1 Dog-owner relationship

Brachycephalic breeds are rising in popularity despite their health issues being more known today. According to a recent UK research, over 60% of brachycephalic dog owners recognized clinical indications of BOAS in their dogs but rejected them as "typical for the breed," despite reporting a high frequency and severity of clinical signs. This is quite alarming since it implies that many pets are suffering from BOAS and aren't getting the care, they need (Ekenstedt et al., 2020). In another study of the pug, French bulldog and English bulldog, 70.9% of owners said their dog was in very good or excellent health. Surprisingly, just 6.8% of dog owners thought their dog was less healthy than the breed average. In the study, all three breeds had exceptionally strong owner-dog connections. Emotional closeness was the highest for pug owners, female owners, and owners without children. Many owners are unlikely to recognize sleep difficulties as a welfare concern, and indications of sleep-related airway obstruction may be misinterpreted as harmless 'normal' occurrences. For instance, if they sleep with a toy in their mouth or sit in a sitting position to avoid upper airway blockage, it is seen as cute quirkiness rather than indications of pathological breathing. When compared to non-brachycephalic dog owners, owners of brachycephalic breeds have been shown to be less affected by breed health and lifespan when selecting a breed. Studies of American Kennel Club registration records show that brachycephalic breed popularity is more closely linked to a dog's physical appearance than to welfare-related breed traits like health and lifespan, resulting in breeds with a higher prevalence of inherited disorders getting more popular (Packer et al., 2019).

7.2 The role of Kennel Clubs

National kennel clubs (KCs) play an important role in the governance and control of dog breeding to enhance the health and welfare of pedigree dogs. KCs are responsible for

maintaining breed standards, as well as the laws that govern the organization of conformation dog shows and working dog shows. Trials are held, and pedigree dogs' genetic information is kept. KCs have frequently been targets of criticism, as an organ to promote extreme breeds with bad health and welfare. However, breeding rules and regulations vary between countries, and in many countries, "purebred" dogs are not registered in KC's and therefore beyond their influence (Wang et al., 2018).

The presence and risk of breeding for extreme morphology have lately been highlighted by the UK Kennel Club. The Kennel Club has a Health and Welfare Strategy Group meant to address the issue. There are, however, numerous breeds whose existing anatomy poses a significant welfare issue, and the case is that if the breed continues to be dominated by physical characteristics with a lower priority placed on health, welfare, and the environment, this is likely to be the case in the future. Therefore, the situation is one that needs urgent addressing (Rooney & Sargan, 2010).

Previously to the documentary "Pedigree Dogs Exposed" in 2008, it was allowed to register offspring of first-degree relatives (siblings, parent-offspring) in the British KC. This became forbidden shortly after airing, in March 2009. The following paragraph also got inserted in all breed standards: *"A Breed Standard is the guideline which describes the ideal characteristics, temperament and appearance of a breed and ensures that the breed is fit for function. Absolute soundness is essential. Breeders and judges should at all times be careful to avoid obvious conditions or exaggerations which would be detrimental in any way to the health, welfare or soundness of this breed. From time-to-time certain conditions or exaggerations may be considered to have the potential to affect dogs in some breeds adversely, and judges and breeders are requested to refer to the Kennel Club website for details of any such current issues. If a feature or quality is desirable it should only be present in the right measure"* (Nicholas, 2011).

"Breed Watch" was another scheme the Kennel Club launched to identify problematic breeds regarding welfare, and as advice to judges, breeders, and exhibitors (Nicholas, 2011). It is meant to discourage breeding and showing of dogs with exaggerated features that are harmful to health. The measure can be found online on the UK Kennel Club website. It is divided into category 2 and 3, which are breeds of concern, and category 1 which are breeds with currently no points of concern. Their booklet covers points of concern for visual assessed areas as nose, mouth, skin, eyes, BCS, tail, and movement. Category 3 breeds

describe breeds with exaggerated conformation which puts them at risk for specific health conditions. The breeds are Bloodhound, Bulldog, Dogue de Bordeaux, Mastiff, Neapolitan Mastiff, Pekingese, Pug, and St. Bernard. Category 2 breeds are breeds that have points of concern for their health, as reported by judges and clubs (Breed Watch, 2021). In 2011 the Kennel Club declared that all category 3 breeds must go through a veterinary health check before they participate in Best of Breeds at Crufts (Veterinary health checks, 2021). Even though most pedigree dogs are never shown, many are bred by breeders who strive to create show-quality animals and whose excess dogs are sold to private homes. As a result, developments in the show dog breeding community have a significant impact on the industry. The whole domestic dog population, as well as decisions made by a single person. The actions of a small number of breeders have consequences for the rest of the industry, the pets, and the public who owns them (Rooney & Sargan, 2010)

The breed standards were revised in England to prevent breeding for extreme morphologies, after the following pressure from the veterinary community, the public, and welfare organizations. In the United States, this has not been done, and many of the breed standards for the American Kennel Club contain encouragement for extreme conformation, such as "extremely large" eyes for certain breeds (Packer, Hendricks, & Burn, 2015)

7.3 The role of veterinarians

According to a survey, as many as 48% of small animal veterinarians advise customers against buying a purebred dog breed because of hereditary diseases (Farrell et al., 2015) and in a 2013 survey by New Zealand veterinarians, the health and wellbeing of the Bulldog, Pug, and French Bulldog were deemed too compromised to continue breeding (Packer et al., 2019).

Veterinarians are part of the profession which holds responsibility for the health and welfare of animals, but they are also expected to be involved in discussions when it comes to breeding practices. Vets can address issues in several stages, with the owner, breeder, the community, and politically. Veterinarians can educate the public about the increased morbidity several breeds face. It is important to have an open and clear dialogue about sensitive and difficult topics, such as giving bad news, discussing pet animal obesity, terminal conditions, and breed-related health issues (Fawcett et al., 2019).

At the level of the owner, many relevant discussions occur after the purchase of susceptible breeds. It’s important to have a conversation about short and long-term welfare issues and associated costs as soon as possible. At the level of breeders, it's crucial to contribute to the improvement of the health of their animals. This can be done by recommending neutering or stopping the breeding of a dog that has had a cesarian section previously or suffers from BOAS. Veterinarians can also refuse to participate in artificial insemination for dogs with known health issues. At the level of the profession, veterinarians can play an active role by collaborating with kennel clubs to emphasize the need for breed standard changes and participating in projects to improve the health and welfare of breeds (Fawcett et al., 2019)

8. Conclusion

The goal of this literature review was to better understand the impact exaggerated breeding has on the health and welfare of pedigree dogs and which consequences have been seen in clinical cases and research so far.

Dogs have been our loyal companions for a long time, and they are completely dependent on us humans for giving them a good life - free from pain and suffering. The sad truth today is that many dogs don't experience this, even when owners have their best interest at heart. The ownership of especially brachycephalic can be said to be a complex phenomenon. The relationship between dog and owner is shown to be extremely strong, and the perception of good health is unrealistically high. It appears to exist errors in owners' perspective when comparing their own dog's health to that of the rest of the breed. This may be explained by cognitive dissonance, as many young brachycephalic dogs suffer from a high level of disease (Packer et al., 2019). The ever-increasing popularity that these breeds experience, also suggests that their owners are not affected by the enormity of the costs linked with health and welfare (Fawcett et al., 2019).

Systematic breeding of more and more exaggerated morphologies has long been going on without much regulation or criticism. In the most severe or diseased breeds where there are said to be no healthy individuals left it can even be referred to as systematic animal abuse. These dogs are suffering just because of humans' vanity. These are, in the majority of cases, the show lines. Other lines, such as the working lines have a different standard to attain. The British Kennel Clubs' slogan "fit for function – fit for life" shows the distinct attitude and expectations that are shown towards these dogs. For the show lines, the function part is undeniably downgraded in importance (Crispin, 2011).

The criticism the recent years have caused some positive development in breeding, as the Netherlands banned breeding of dogs with too short muzzles in 2014, and in 2020, the Norwegian Society for Protection of Animals sued the Norwegian kennel club, Norwegian bulldog club, Norwegian cavalier king Charles spaniel club and several breeders for breaking the animal welfare law § 25.

It is important that welfare organizations, the veterinary profession, breeders, and other relevant associations unite to find a new model of breeding practices. Since different breeds of dogs are confined populations, and therefore have variations in levels of specific

disorders, there will be some variations to the approach for their remedy, even though the core changes needed are the same (Rooney & Sargan, 2010).

Many breeders have understood the importance of avoiding inbreeding, but do not look far back enough in the pedigree for common lineages. Others still believe in inbreeding as they want the ideal anatomical features as stated in the book of breed standards (Rooney & Sargan, 2010). These breeders and those responsible for upholding the breed standard in different pedigrees are having a hard time accepting certain morphological changes which are needed to better the breed standard and improve their health. Breed standards are continuously changing, as many individuals of breeds 100 years ago wouldn't be accepted by the modern breed standard today. A breed would therefore not be "lost" or "destroyed" by changing certain features, but rather be evolving back to a healthier appearance. This means that many breeds can still ethically be kept if functionality and health get prioritized over appearance again. It is done by increasing the outcrossing, sometimes even with a different breed, though they need to be health tested as well, as opposed to the trend of designer dogs and leaving the dogs with the more extreme conformations out of the breeding program. Outcrossing with other breeds has been done before, after the ban of tail docking. A naturally bob-tailed boxer was produced by crossing it with a Welsh corgi, and then back to boxer again. The 3rd generation boxer-cross was even registered with the British Kennel Club and won prizes. Ironically, this was done only for aesthetic purposes, and sadly indicates the incentive that drives certain members of this industry. However, it still shows the possibility and value of outcrossing (Rooney & Sargan, 2010).

"The use of healthy animals true to their species in behavior and looks, when applicable, showing a sustainable performance" is considered to be the definition of ethical breeding. It still leaves room for breeding towards aesthetic goals if these are non-harmful for the animal. This is not the case in many breeds today (Broeckx, 2020) Breeds and lineages which does not have any healthy individuals left should be considered abandoned, as it would not be ethical to breed suffering or diseased dogs, even when the attempt is to better the health of future generations. Veterinarians have an obligation, both professionally and morally to minimize and prevent the health and welfare impacts caused by exaggerated phenotypes and inbreeding. Both systematically and at the level of the patient (Fawcett et al., 2019).

9. Summary

The breeding of dogs has a long history, and breeds change continuously as humans come up with new ideas or goals for the different breeds. Health issues arise when breed standards call for extreme morphology which isn't compatible with anatomical function or when a narrow gene pool is continuously used to homogenize an otherwise normal-looking breed. Breed-related disorders can therefore be divided into conformational-related -, and non-conformational-related disorders. There have been attempts to measure the decreased quality of life these breeds experience, by the generic illness severity index in dogs (GISID).

Extreme brachycephalic breeds, like the pug, English bulldog, and French bulldog experience a wide array of symptoms and disorders caused by their conformation and reduced genetic diversity. This includes pathologies in the respiratory-, cardiovascular-, and digestive systems among others. Surgeries are possible to alleviate some of the symptoms, but today, there aren't any complete fixes for the dogs that are the most severely affected. The breed standards are continuously changing in Kennel Clubs in different countries and the last few years, the focus has increased to better the welfare for vulnerable pedigrees. The ethical issues with breeding are moving forward, but there is still a long way to go if the goal is to optimize animal welfare for our companion animals, which is what it should be.

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Contact information (e-mail): martinelefstad_19@hotmail.com

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Number of files submitted: 1

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