Bite Force and Bite Pressure: Comparisons of Humans and Dogs
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"Jaws of steel!" "Locking jaws!" "A 2000 pound per square inch bite pressure." These are just a few of the plethora of statements describing the dog referred to as the "pit bull". The "pit bull" is a term encompassing several breeds, the American Pit Bull terrier, the American Staffordshire terrier, the Staffordshire terrier, and the Bull terrier. Other breeds or mixed breeds may be included due to their physical resemblance to the pit bull. Every year the media hype continues with a perpetual series of disinformation, myth, and distortions that bedevil the bull breeds. The media bombards the public after a dog attack incident perceived to involve one of the bull breeds. Descriptions of the incident talk about ferocious bite pressures, quoting upwards of 2000 pounds per square inch (psi). In another article, we read about the "scissors bite", leading one to believe this to be some sort of demonic configuration. Are the bull breeds different? No! The American Pit Bull terrier and all the related bull breeds are dogs. They are anatomically and physiologically no different from the Labrador retriever or the poodle. All mammals have the same basic structures of the jaw. Variations and adaptations are dependent on whether the primary diet is herbivore as with humans or carnivore as with dogs.

What are the differences between the human and canine jaw? What is the bite force and bite pressure in dogs? Moreover, how does this compare within the context of the human bite force? Without some comparison and understanding of how we measure bite force and bite pressure the numbers alone are meaningless. The current article describes briefly the general mammalian jaw structure; reviews the current knowledge of bite force and bite pressure in both humans and dogs. In addition, the article looks at the question can the bite force and bite pressure of the dog be accurately measured and, if so, how does it compare to a human bite?

Jaw Structure

The human and canine jaw structure has similar basic components (figure 1). The mandible or lower jaw is one of the strongest bone structures in the body. The arm out of the plane of the teeth is a structure called the ramus, one on each side. The rami terminate in the condylar process and the coronoid process. The condylar process makes up part of the temporomandibular joint (TMJ) or jaw joint. In humans, the TMJ is a double hinge joint that allows for a complex series of movements of the jaw, more than just simply opening and closing. Due to the non-rigid hinge connections in humans, the TMJ can be displaced or dislocated. Fractures are not uncommon in humans. A great deal of the strength of the jaw comes from the action of the muscles that allow us to chew our food. These muscles are the temporalis, the masseter, and the pterygoids. The temporalis muscle attaches at the coronoid process of the mandible and across the top of the head. The masseter is one of the most powerful in chewing and predominant

in humans. The pterygoids, medial and lateral, allows for the side to side movement pronounced in humans. The dominance of one or more of the muscles in bite force depends on whether you are looking at a carnivore or herbivore.

Humans have a jaw structure that is herbivore, the jaw joint is well above the plane of the teeth and the mouth opening is small. In humans the coronoid process, mandibular notch, and condyle form what would appear as a “saddle” type structure. This type of joint while not as stable as the simple hinge joint of the carnivore, allows for a greater degree of movement. When the mouth opens, two distinct motions occur at the joint, essentially a “double-joint”. The movement of the condylar process and a cartilage disk in the joint allows motion to take place in 2 planes. There is a forward-backward (anterior-posterior) motion and lateral (side-to-side) motion in addition to opening and closing of the jaw. Take a moment and place your thumb and fingers on your jaw, just in front of your ears. You should easily feel the motion of the joint opening, closing, forward, backward, and side to side. The temporal muscle is not as pronounced in humans, the larger ramus allows for a greater role of the masseter and the pterygoids muscles. The masseter muscle which covers most of the body of the rami is thick, allows for the closing of the mandible, and is one of the most powerful muscles and the primary one in determining bite force in humans. The medial and lateral pterygoid muscles allow for a variety of movements to elevate the mandible as well as for lateral and side-to-side movements. The human jaw is designed for chewing. When the jaw comes together in what is called occlusion, the length of the jaw more or less closes at once. The occlusal contact area is the biting surface of the teeth. The teeth are closely grouped forming platforms for crushing and grinding and hence designed to exert substantial pressure. The human jaw allows the chewing or mastication of food by this complex series of movements. Humans chew, roll the food around, grind, mince, and swallow. The strength of the jaw, and hence the force exerted, is going to be affected by adaptation to the type of food consumed. Chewing is both learned and automatic. Chewing exerts a force and hence pressure on the surface of the teeth. As we chew mechanoreceptors serve as a feedback mechanism to the brain, identify the texture of the food in the mouth as soft, hard, or brittle, from which we learn how much force or pressure is necessary. We do not really stop to think about the dynamics involved until we bite down on something unexpected like the pit of an olive or a piece of shell from a nut. The result may mean a chipped, broken, or severely fractured tooth and a trip to the dentist.

Dogs, as carnivores, have much simpler jaw structure and depending on the breed, the mandible is short as in a pug or English bulldog, or long, as in the German shepherd or collie. The coronoid process is larger and the condyle is in the plane of the teeth. The mouth opening is wide which is advantageous in utilizing the force needed to seize and kill prey. The jaw joint is a simple hinge joint that is very stable. The mandible of the dog can not move forward and

backward as in humans. There is little room for movement other than opening and closing. The presence of the longer canine teeth would interfere with lateral movement. The masseter and pterygoid muscles are smaller. The temporalis muscle that attaches at the coronoid process and across the top of the head is the most pronounced and strongest muscle. When you pet the top of your dogs head, you are petting the temporalis muscle. In the simpler carnivore jaw structure the joint acts as a pivot point. The jaw comes together in a back to front motion, like the blades on scissors, hence the "scissors bite". The speed and force of this closure to capture and secure prey is important to a carnivores' survival. Dogs do not have the continuous dentition as humans do; they have diastimas or spaces between their teeth so as not to trap stringy debris when consuming prey. Dogs are not set up for extensive chewing of food, but rather for tearing and swallowing the food whole. Watching your dog eat, you will see very little chewing, the jaw opens and closes with little side to side motion as humans do.

Bite Force

How does this relate to bite force and bite pressure? When talking about bite force what is it that we are measuring? A force is a physical exertion or action on an object in a particular direction. The operation of the jaw structure is that of a simple lever. The bite force is the ratio of the distance from the jaw joint which is the fulcrum or pivot point to the point of application, i.e. what you are biting versus the distance from the jaw joint to the muscle attachment which is the force required to close the jaw. The force unit most familiar is the pound (lb-f).

Diet is a key factor in developing the bite force. For humans, a populace that has as their main staple grains that are coarsely milled or a food that is frozen is going to have a more developed muscle structure than a populace eating "soft" foods. Today's softer diet as seen in most of the developed western culture has a lot less of the muscle building than would be seen in our ancestors. Another factor that affects bite forces in humans is clenching of one's teeth and gum chewing, processes that can develop the masseter muscle. For dogs and other carnivores, being able to rapidly and with sufficient force close the mouth and seize a prey is of primary importance.

The measurement of the bite forces in humans is relatively easy. A measuring device, essentially a force transducer, is directed to a particular location, a bite point source of a specific tooth as well as a general bite force over the whole dentition. Measuring the force in a dog involves some variation of the transducer. The key task is to entice the dog to chew on the device in a "natural" manner. Placement of the device in a particular area of the dog's mouth is more difficult, so when measuring you really have a general measurement of the bite force as opposed to the point force of any given area. Electrostimulation of the muscles of anesthetized subjects is another method used particularly on animals. However, with this method you have only measurements of muscle strength, not

a natural action. A recent method for measuring human bite force and bite pressure is the use of a pressure sensitive film. Biting on the film releases a microencapsulated dye that correlates with the force of the bite and measured by a densitometer. Data however from the various studies are not very easy to evaluate due to differing designs, placements, and accuracy of the transducers.

Table 1 shows some of the bite force data determined in humans and dogs as well as comparison to studies in other animals. For humans the larger bite forces observed are from measurements in the posterior teeth, the molar region. The molar region is closest to the pivot point of the jaw and the muscles associated with the jaw strength. At the incisors or anterior point, the bite forces are lower with less action of the jaw muscles. A strong bite force in humans is expected due to the shorter jaw, and the point force of the bite is localized on the molars and premolars. The bite forces range from 55 lbs to 280 lbs., averaging 162 lbs and in some cases reaching a maximum of over 970 lbs. The force observed for the incisors in the front is lower at 22 lbs to 34 lbs. The bite force measurements of dogs also have a wide range. These bite forces were measured using a force transducer disguised as a rawhide chew. The bite force measured on about 20 pet dogs representing 12 different breeds and mixed breeds ranged from 3 lbs for a West Highland terrier to 313 lbs for one Rottweiler. The bite force measured for any individual dog varied and is for a few seconds duration. No human or dog would be able to maintain these forces over an extended length of time. The wide range of bite forces in dogs is expected given the range of sizes in breeds, from dogs weighing only about 10 pounds to the larger breeds up to 150 pounds. In dogs with the longer jaw, the bite forces are going to be much lower at the incisors.

Bite Pressure

How does bite force relate to the bite pressure? Pressure is the force exerted on a given unit of area. The pressure unit most commonly used is the pounds per square inch or psi. The force-pounds exerted on a 1-inch square surface area is going to be much greater than that same force distributed over a larger area. If a person wearing tennis shoes inadvertently steps on your toes with the heel, it will be noticed, but would not be very uncomfortable. However, if you encounter a woman wearing stiletto heels who steps on your toes, you are going to feel that far more painfully. This is because the force of that person's weight is directed into a much smaller area. We would all agree a bite from either a human or an animal hurts. However, some comparisons of what these forces might be keeps them within context and perspective relative to something we know about, i.e. a person.

The bite pressure in humans, like the bite force, can be relatively easily measured. In using the pressure sensitive film, the bite force can be associated with a defined occlusal contact area. When the volunteers for the study were asked to bite down on the film with increasing pressure (clenching) the contact

area increases. As the force increased, the contact area of the bite increased and the bite pressure remained constant. The force is dissipated over a slightly larger area. The average bite pressure is in the range of 2840 to 4270 psi. . Therefore, while the bite force itself averaged 117 to 265 lbs, the pressure remained constant at about 5600 psi…certainly enough to puncture light weight sheetmetal.

So what is the bite pressure of a dog? That is not known accurately yet. In a couple of veterinary dentistry texts bite pressure values range from 305 to 798 psi to 7111 to 49782 psi. However, no reference is given of how these values were obtained. The large values reported may actually be compressive properties of the tooth. For humans a tooth can have a compressive strength of up to 30,000 psi before shattering. One often-quoted statement of how a dog's bite has the strength to perforate sheet metal is from a study performed over 30 years ago. The study was on military dogs describing a bite pressure of 150 to 450 psi that could penetrate the sheetmetal on the protective device. Again there is no information on how these values are determined.

Currently with all the different factors involved the bite pressure of a dog can not be measured accurately. It would be difficult to place a device accurately and consistently in a dog's mouth to obtain accurate readings. The intensity of the bite pressure, as with the biting or pulling force, is also going to depend greatly on the enthusiasm of the dog to bite. Humans however have a very powerful bite pressure, especially with a short jaw and very powerful jaw muscles.

A Final Word

The preceding article just skims the surface regarding the information on the TMJ that is known in humans. Textbooks and scientific articles abound on the TMJ, malocclusions, and diseases and disorders that affect humans. The mammalian jaw can exert a force of tremendous strength. Any bite from any mammal, small or large, can certainly cause damage. There is nothing out of the ordinary in jaw structure or anatomy of the bull breeds. There is no "locking-jaw". On rare occasions the non-rigid hinge structure of humans can result in the joint "locking". Medical intervention is required to re-set the jaw properly. A similar situation in carnivores would put their survival at risk. The strength of the bull breeds' bite comes from their tenacity to hold a grip, not from any physical or physiological abnormality that gives them super strength.

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Figure 1: Structure of the dog and human jaw. Mandible (M) the main body of the lower jaw; the Rami (R), a broad structure out of the place of the teeth; the Coronoid Process (CP) sits within the zygomatic arch and is the point of attachment for the temporalis muscle (TM); the Condylar Process (CY) that is the temporomandibular joint. The masseter muscle is across the rami, a much larger structure in humans. The Medial and Lateral Pterygoids are more prominent in humans than in dogs. Drawing by Linda Ruth Cooper.

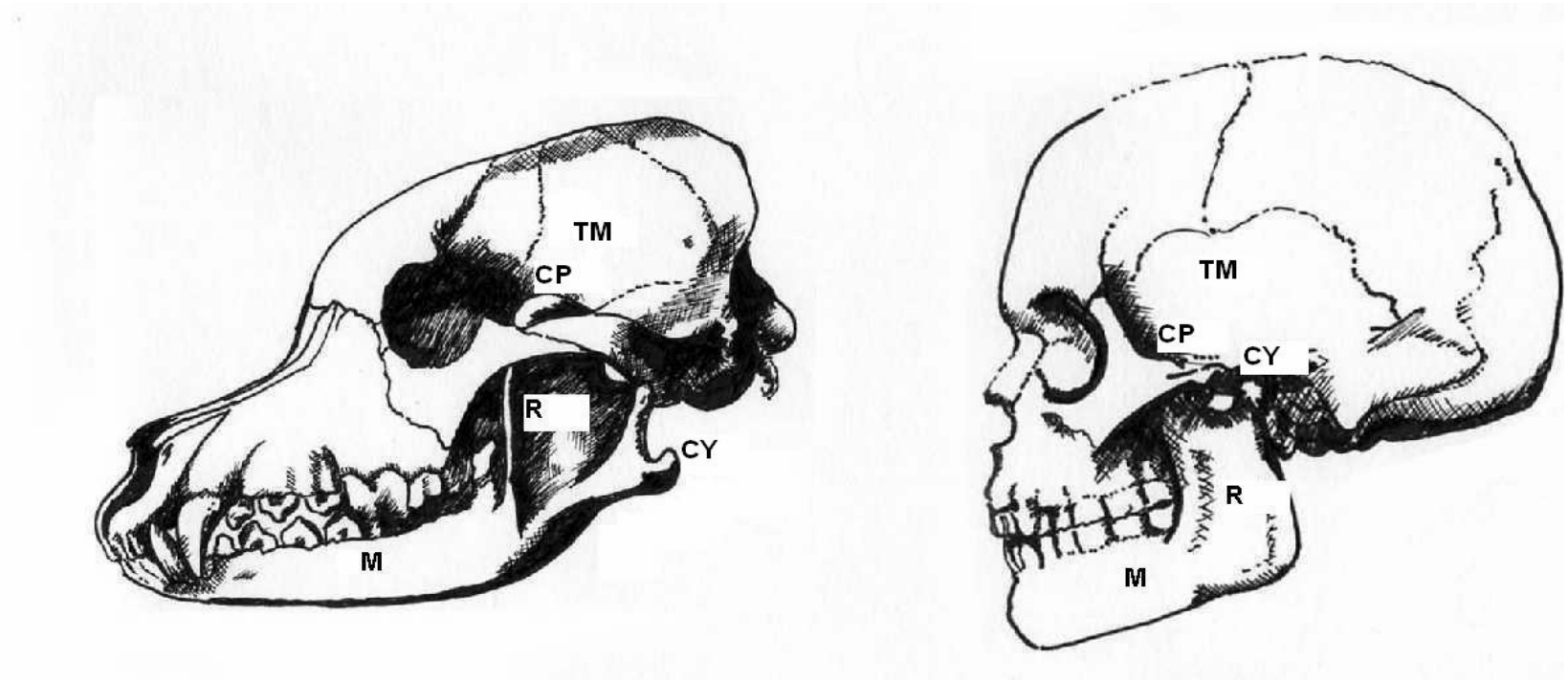

Table 1: Bite force measurements determined for humans and dogs.

Subject	Bite Force	Reference
Humans	Range: 55-280 lbs Average: 162 lbs. Max: 975 lbs. incisors 22.5-33.7 lbs canines: 72.6-109 lbs premolars: 95.3-131 lbs 1st molars 67.4-89.9 lbs 2nd molars: 107-168 lbs	1-4
Dogs	Range: 2.9-313 lbs Average: 58 lbs	5,6
Hyenas	Average 56-337 lbs max. 1010 lbs.	7
Some other examples: Dusky Shark Orangutans African Lions Alligators Tyrannosaurus Rex	 325 lbs. 385 lbs 938 lbs. 2200 lbs. 3000 lbs.	8,9

References:

1. Gibbs, C.H., et. al. (1986) J. of Prosthetic Dentistry. 56: 226-229.
2. Van Eijden, T.M.G.J. (1991) Arch. Oral Biol. 36: 535-539.
3. Zarb, G.A. et. al. In Temporomandibular Joint and Masticatory Muscle Disorders. (1994) p. 110. Mosby.
4. Hidaka, O. Saito, I.M. and Morimoto, T. (1999) J. Dent. Res. 78: 1336-1344.
5. Strom, D. and Holm, S. (1992) Arch. Oral Biol. 37: 997-1005
6. Lindner, D.L. et. al. (1995) J. Vet. Dent. 12: 49-52.
7. Binder, W. and Van Valkenburgh, B. (2000) J. Zool. (Lond.) 252:273-283
8. Erickson, G.M., Lappin, A.K., and Vliet, K.A. (2003) J. Zool. (Lond.) 260:317-327.
9. Erickson, G.M., et. al. Nature (1996) 382:706-707.
10. Chamber, GH and Payne, Minnesota Medicine (1969) 52: 427-430.
11. Kesel, ML, “Veterinary Dentistry for the Small Animal Technician.” Iowa State Univ. Press (2000) pgs. 185-187.
12. Tholen, MA. “Concepts in Veterinary Dentistry”. (1983) Vet. Med. Publishing. p. 135.
13. Eisenmenger and Zetner. “Veterinary Dentistry”. (1985) Lea&Febiger. p.12.