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A1_4 Biting the Bullet

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Abstract

Catching a bullet between the teeth has been a magic trick from as early as 1586. Here we investigate if, assuming they were able to catch a bullet, human teeth can withstand the shear stress applied by the decelerating bullet. We find that the shear stress of catching a bullet along the molar teeth, 2.99×10^8 Pa, is 6.48 times greater than the maximum shear strength of human teeth. Additionally, we find that the number of pairs of molars needed to stop a bullet without reaching the maximum shear stress of human teeth is 20.

Introduction

Catching a bullet, by hand or between the teeth, has been a common magic trick for centuries, with the earliest documented bullet catch occurring in 1586 [1]. As with most magic tricks, there is no single way the trick is performed. Typically the gun or bullet is modified, and the magician conceals a replica bullet in their sleeves or in their mouth. We have investigated whether human teeth could withstand the shear stress caused by the force of decelerating a bullet, assuming it is possible to completely stop a bullet in the teeth. We also calculated the number of teeth required to stop a bullet without reaching the average shear stress threshold of human teeth.

Theory

In order to provide the greatest surface area for the bullet to be in contact with, we assumed the bullet was slowed between a set of 6 molar teeth (i.e. 3 top and 3 bottom). Each molar tooth is on average 10.8 mm long and 11.5 mm wide (from the perspective of the bullet travelling parallel to the molars) [2]. Note that for simplicity we assume the molars are flat rectangles of the given dimensions. The maximum stopping distance available to the bullet is the length of 3 molars, 32.4 mm. Given an initial velocity of 341 m s^{-1} [3] and a stopping distance of 32.4 mm, we found the deceleration of the bullet to be 1.79×10^6 m s^{-2} using

$$v^2 = u^2 + 2as \tag{1}$$

where v is final velocity in m s^{-1}, u is initial velocity in m s^{-1}, a is the deceleration of the bullet in m s^{-2} and s is the distance travelled in m.

We then found the force applied by the decelerating bullet using

$$F = ma \tag{2}$$

where F is the force applied to the teeth by the decelerating bullet in m s^{-2}, m is the mass of the bullet in kg and a is deceleration of the bullet as defined previously. Assuming a bullet mass of 0.124 kg [3], we found the force of the decelerating bullet to be 2.23×10^5 N.

The shear stress applied by a force is given by

$$\tau = \frac{F}{A} \tag{3}$$

where τ is the resultant shear stress in Pa, F is the force applied and A is the cross-sectional area parallel to the applied force. Assuming the bullet stops when in contact with a total of 6 molar teeth, the parallel surface area A in contact with the force is the surface area of 6 molars, 7.452×10^{-4} m^2. Hence, we found the applied shear stress on the teeth by a decelerating bullet to be 2.99×10^8 Pa.

Discussion

Pioch and Staehle (1996) found the maximum shear strength of human teeth (the mandibular premolars) is 46.15×10^6 Pa [4]. Hence, we found that the shear stress applied by a bullet is 6.48 times the maximum shear strength of human teeth. Note that we have assumed the applied force is spread evenly across the teeth rather than just the point of first contact, effectively modelling a single large tooth.

Given the maximum shear stress human teeth can withstand, we used equations (2) and (3) to find the number of pairs of top and bottom teeth (providing an increased surface area) needed to lower the applied shear stress to the maximum shear strength of human teeth (46.15×10^6 Pa). We found this number to be 19.4. Therefore, a set of molar teeth 20 long could stop a bullet 'safely' (assuming the force is spread evenly along the full length). We have shown that even if it was possible to completely decelerate a bullet using teeth, the resultant shear stress would at least stip the tooth's enamel from the underlying dentin and would be extremely dangerous.

An episode of 'Mythbusters' investigated catching a bullet in the teeth using a pig's head, and found that the pig's jaw (which was assumed to be stronger than a human's) could not withstand the shear stresses present [5]. They concluded that if a pig could not withstand the force of a decelerating bullet, neither could a human.

Conclusion

In conclusion we found the shear stress created by decelerating a bullet along a row of 3 molars was 2.99×10^8 Pa. This is 6.48 times the maximum shear strength of human teeth. Additionally, we found the number of pairs of molars needed to decelerate a bullet without reaching their maximum shear strength to be 20.

Our findings align with those of an episode of 'Mythbusters' in which they conclude that since a pig's jaw could not withstand the forces involved in catching a bullet, neither could a human jaw.

References

[1] `https://conjuringarts.org/exhibitions/the-bullet-catch/` [Accessed 11 October 2019]

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[4] T. Pioch and H. J. Staehle, *Experimental investigation of the shear strengths of teeth in the region of the dentinoenamel junction*, (1996).

[5] `http://kwc.org/mythbusters/2006/02/mythbusters_catching_a_bullet.html` [Accessed 20 October 2019]