Orthodontic tooth movement: ideal rate and force

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" Describe and discuss the concept of the ideal rate and force for Orthodontic tooth movement. Provide evidence for and against the claims of this ideal".

Orthodontic tooth movement is a process that combines pathologic, physiologic and biological responses to externally applied forces (Wise, & King, 2008). It is explained by the pressure tension theory and bone bending theory. Pressure tension theory states that tooth movement occurs in the periodontal space by creating a pressure side and a tension side (Schwarz, 1932). Conversely, bone bending theory states that force delivered, results in bending of the tooth and its surrounding structure, whilst altering the cellular activity for bone remodelling. Additionally, tooth movement is also comprised of three phases, which include the initial phase, lag phase and post lag phase (Burstone, 1962). Currently, there is being a shift, from the emphasis on force application to the biological and biochemical factors affecting tooth movement (Mayne, 2014). Nevertheless, understanding of the force magnitude and its temporal characteristics is important determining the ideal rate and force of orthodontic tooth movement. Study conducted by various scientists, showed that variables such as: force magnitude; continuous vs intermittent force; individual variations; tooth variations and different types of tooth movement play a role in determining the ideal and rate and force of tooth movement.

Studies by Hixon et al. (1970) showed that higher forces moved teeth farther in 8 weeks than lighter forces. The studies showed an increase in maxillary canine movement in all but one of the subjects. The trials demonstrated that

as the force increased from 200 grams to 300 grams, the tooth movement for patient B increased from 0. 15 mm/week to 0. 25 mm/week. This is a result of the higher forces generating a metabolic response sooner and at a more rapid rate, resulting in an increased tooth movement. Additionally, study conducted by Andreasen, and Johnson (1967) on sixteen females, showed teeth exposed to the 400 grams moved further than 200 gm, at a rate of 2. 5 times to that of the lower force. Moreover, heavier force, also cause an increased anchor teeth movement (Storey, 1973). However, studies by Owman-moll, Kurol, and Lundgren (1996) have claimed that maximum tooth movement can be achieved even with light forces. This is also supported by Storey (1973), who stated little differences in canine movement between heavy and light forces. Moreover, Ren, Maltha, Kuijpers-Jagtman (2003) support this viewpoint by stating that, there is no specific optimal force but a wide range of forces evoke a biological response in the periodontal tissue for ideal tooth movement. Additionally, Owman-moll et al. (1996) through their studies showed that, while heavy forces increase tooth movement, they can also damage the tooth and increase the rate of root resorption. Storey (1973) observed that some trauma is associated even with applied light orthodontic forces. In order to produce adequate biological response in the periodontium, light forces cause frontal bone resorption but heavy forces can cause PDL necrosis, along with bone and root resorption (Krishnan, & Davidovich, 2006). Hence, an optimal force is an extrinsic mechanical stimulus, with the aim of restoring the equilibrium of periodontal supporting tissue remodelling via cellular response. It should lead to a maximum rate of tooth movement, while ensuring minimal irreversible root, PDL and alveolar bone damage. Also, this force should produce a maximum

rate of tooth movement, whilst ensuring patient comfort (Proffit, Fields, & Sarver, 2013; Ren at al., 2003).

Teeth react differently, depending on whether the force is continuous or intermittent. Studies by Oates, Moore, and Caputo (1978) showed tooth movement exposed to low level of intermittent tooth forces were equal to that of continuous forces. But at higher force levels, intermittent forces produce greater tooth movement within a shorter period of time. However, results from study conducted by Owman-Moll, Kurol, and Lundgren (1995) showed continuous forces (4. 3mm +/- 1. 5mm) were more effective than intermittent forces (2. 9 +/- 0. 6mm) in achieving tooth movement. Furthermore, the study also showed no significant root resorption differences between the two forces in the end. Proffit et al. (2013) believe that effective tooth movement occurs with longer and continuous forces between 4 – 8 hours. They also believe that light continuous forces produce the best tooth movement and these forces should be light enough to ensure only frontal resorption. However, heavy continuous forces should be avoided due to tissue damage but heavy intermittent force is clinically acceptable although it is less efficient.

Study conducted by Hixon et al. (1970) showed the role of individual variation affecting tooth movement, with some individuals displaying increased movement than others. These individual variations are in regard with different root areas, metabolic responses and facial growth. The variations resulted in altered time and rate of tooth movement between individuals. Additionally, older patients with lower metabolism and increased facial growth showed less movement, in comparison to a younger patient.

The variation is also attributed to differences in tissue characteristics. The younger patients have many celled periodontal membrane; uncalcified osteoid bone crest lining; and loose fibrous marrow space tissue, meaning that they reach the proliferation stage of tissue changes earlier than older adults. This will result in tooth movement (initial phase) starting earlier in younger people (Reitan, 1957). Additionally, Pilon, Kuijpers-Jagtman, and Maltha (1996), stated that individual differences in bone density, metabolism and PDL turnover can also be responsible for the variations. Each individual has his/her optimum pressure for tooth movement and that in slow movers; the optimum forces were not applied.

Hixon et al. (1970), though his study demonstrated different teeth having different optimal rates and force for tooth movement. The results noted an increased canine movement, in comparison to molars. This is due to the root surface area of the canine being lesserthan molar, with the forces being distributed over a larger area rather than being concentrated (in the case with canines). Moreover, Proffit et al. (2013) also support this theory through their table, which shows a smaller force for anterior teeth and a larger force for posteriors. Additionally, Smith and Storey (1952) stated the optimum range for the maximum rate of movement is 150-200cN for canines with later studies by Lee (1964) increasing the range to 260cN. Through their studies, Lundgren, Ownman-Moll, and Kurol (1996) stated the ideal rate of horizontal tooth crown movement was 0. 8 mm during the first week and 3. 7mm after 7 weeks. However, intraoral location also makes a difference, with maxillary canines having an increased movement in comparison to their mandibular counterparts (Hixon et al., 1970). However, Ren, Maltha, and

Van' t Hof (2003) stated no differences in movement between the maxillary and mandibular canines. Hence, the implications of intraoral location on tooth movement are still unclear.

Proffit et al. (2013) have stated that different types of tooth movement have different optimal forces and these include: tipping movement (35-60 gm); translation (70-120 gm); root uprighting (50-100gm); rotation (35-60 gm); extrusion (35-60gm) and intrusion (10-20 gm).

Using results from past studies, along with the consideration of the above variables, Quinn, and Yoshikawa (1985) have developed four hypotheses, related to force application and tooth movement. Hypothesis 1 is a constant relationship and Hypothesis 2, is linear relationship between the rate of tooth movement and stress. Hypothesis 3 states that increasing stress increases the rate of tooth movement to a maximum after which the rate declines with additional stress. Lastly, hypothesis 4 states that tooth movement increases with stress up to a point after which additional stress causes no increase in tooth movement. Quinn and Yoshikawa support hypothesis 4, as it supported by extensive experimental and clinical data. This hypothesis is also supported by Hixon et al., with his results showing a lack of tooth movement after a certain force application. But Ren, Maltha, and Van' t Hof (2003), challenged this model due to a lock of available data with high forces, and created a new mathematical model, where shows no tooth movement with no force, but as the force increases, the movement also increases until a certain force, after which the movement stays constant or slightly decreases but will never become negative. This is in contrast to hypothesis 4, which stated the movement as being constant but never decreasing.

From the above essay, we can see that there is still a lack of definite answer for an ideal force and rate of tooth movement, and this can attributed to four main reasons. The first reason is due to a lack of ability to calculate stress and strain at the periodontal ligament. Most studies discussed above, were based on the application of the force to the tooth, but not the forces leading to biological reactions. The second reason is due to the lack of tooth movement control, with most studies involving tooth tipping which causes uneven stress distribution in periodontal ligament. Moreover, measurements are made at the crown, and not at the stress areas, resulting in force overestimation. Additionally, many of the studies were conducted during a short period of time, making the data relevant only for the first two phases of tooth movement. Lastly, variation both among and within individuals, makes it difficult to calculate optimal force and rate, as each individual has his/her individualised optimal values (Ren, Maltha, & Kuijpers-Jagtman, 2003).

In conclusion, we can see that more studies need to be conducted to determine the ideal rate and force of orthodontic tooth movement. Tooth movement is affected by factors such as: force magnitude; individual and tooth variation; intermittent or continuous forces and different types of tooth movement. Additionally, Quinn and Yoshikawa believed that tooth movement increases with stress up to a point after which additional increases create no movement. But this was challenged by Maltha, who stated that the movement can also decrease. The above factors, in addition to the four main reasons discussed above show that there is no ideal rate and force of orthodontic tooth movement.

REFERENCES

Andreasen, G., & Johnson, P. (1967). Experimental findings on tooth movements under two conditions of applied force. *The Angle orthodontist, 37(1),* 9-12. Retrieved from: http://www. angle. org/doi/pdf/10. 1043/00033219(1967)037%3C0009: EFOTMU%3E2. 0. CO%3B2

Burstone, C. J. (1962). The biomechanics of tooth movement *. Vistas in orthodontics, Lea & Febiger, Philadelphia,* 197-213.

Farrar, J. N. (1888). *A Treatise on the Irregularities of the Teeth and Their Correction: Including, with the Author's Practice, Other Current Methods* (Vol. 1). De Vinne Press.

Hixon, E. H., Aasen, T. O., Arango, J., Clark, R. A., Klosterman, R., Miller, S. S., & Odom, W. M. (1970). On force and tooth movement. *American Journal of Orthodontics , 57* (5), 476-489. doi: 10. 1016/0002-9416(70)90166-1

Krishnan, V., & Davidovitch, Z. E. (2006). Cellular, molecular, and tissue-level reactions to orthodontic force. *American Journal of Orthodontics and Dentofacial Orthopedics, 129(4),* 469-e1. doi: 10. 1016/j. ajodo. 2005. 10. 007

Lee, B. W. (1965). Relationship between tooth-movement rate and estimated pressureapplied. *Journal of dental research, 44(5),* 1053-1053. doi: 10. 1177/00220345650440051001

Lundgren, D., Owman-Moll, P., & Kurol, J. (1996). Early tooth movement pattern afterapplication of acontrolled continuous orthodontic force. A human experimental model. *American journal of orthodontics and*

dentofacial orthopedics, 110(3), 287 295. doi: 10. 1016/S0889-5406(96)80013-8

Mayne, R. (2014). DEN2CGD, Lecture 11, Topic 2, Physiology of orthodontic tooth movement [Point slides]. DEN2CGD, Bendigo, Australia: La Trobe University, Department of Health Sciences.

Oates, J. C., Moore, R. N., & Caputo, A. A. (1978). Pulsating forces in orthodontic treatment. American journal of orthodontics, 74(5), 577-586. doi: 10. 1016/0002-9416(78)90033

Owman-Moll, P., Kurol, J., & Lundgren, D. (1995). Continuous versus interruptedcontinuous orthodontic force related to early tooth movement and root resorption. The Angle Orthodontist, 65(6), 395-401. Retrieved from: http://www. angle. org/doi/pdf/10. 1043/00033219(1995)065 <0395: CVICF %3E2. 0. CO%3B2

Owman-Moll, P., Kurol, J., & Lundgren, D. (1996). The effects of a four-fold increasedorthodontic force magnitude on tooth movement and root resorptions. An intra individual study in adolescents. The European Journal of Orthodontics, 18(3), 287 294. doi: 10. 1093/ejo/18. 3. 287

Pilon, J. J., Kuijpers-Jagtman, A. M., & Maltha, J. C. (1996). Magnitude of orthodonticforces and rate of bodily tooth movement. An experimental study. American Journal of Orthodontics and Dentofacial Orthopedics, 110(1), 16-23. doi: 10. 1016/S0889 5406(96)70082-3

Proffit, W. R., Fields Jr, H. W., & Sarver, D. M. (2013). Contemporary orthodontics. StLouis, Missouri: Mosby

Quinn, R. S., & Ken Yoshikawa, D. (1985). A reassessment of force magnitude inorthodontics. *American journal of orthodontics, 88(3),* 252-260. doi: 10. 1016/S0002 9416(85)90220-9

Reitan, K. (1957). Some factors determining the evaluation of forces in orthodontics. *American Journal of Orthodontics, 43(1),* 32-45. doi 10. 1016/0002-9416(57)90114-8

Ren, Y., Maltha, J. C., & Kuijpers-Jagtman, A. M. (2003). Optimum force magnitude fororthodontic tooth movement: a systematic literature review *. The Angle orthodontist, 73(1),* 86-92. Retrieved from: http://www. angle. org/doi/full/10. 1043/00033219(2003)073%3C0086: OFMFOT%3E2. 0. CO; 2

Ren, Y., Maltha, J. C., Van't Hof, M. A., & Kuijpers-Jagtman, A. M. (2004). Optimum force magnitude for orthodontic tooth movement: a mathematic model. *American journal of orthodontics and dentofacial orthopedics, 125(1),* 71-77. Doi 10. 1016/j. ajodo. 2003. 02. 005

Schwarz, A. M. (1932). Tissue changes incidental to orthodontic tooth movement. *International Journal of Orthodontia, Oral Surgery and Radiography, 18(4),* 331 352. doi: 10. 1016/S00996963(32)80074-8

Storey, E. (1973). The nature of tooth movement. *American journal of orthodontics, 63(3),* 292-314. doi: 10. 1016/0002-9416(73)90353-9

Storey, E., & Smith, R. (1952). Force in orthodontics and its relation to tooth movement. *Aust Dent , 56* (1), 11-8.

Wise, G. E., & King, G. J. (2008). Mechanisms of tooth eruption and orthodontic toothmovement. *Journal of dental research, 87(5),* 414-434. doi: 10. 1177/154405910808700509