International Journal of Community Medicine and Public Health
Sawas MA et al. Int J Community Med Public Health. 2022 Feb;9(2):932-936
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20220047

Review Article

Mechanical properties and clinical significance of orthodontic wires

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Received: 20 December 2021
Accepted: 05 January 2022

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ABSTRACT

Orthodontic treatment is usually conducted by applying forces to certain teeth to move them into a targeted position. Orthodontic wires have been reported to be the primary modalities used in fixed-appliances-based orthodontic treatment to induce favorable tooth movement events. Accordingly, acquiring adequate knowledge about these approaches' clinical applications and biochemical behavior is essential when planning for a successful orthodontic treatment. Orthodontic wires are widely used and are mainly composed of composites, polymers, alloys and metals. Accordingly, the physical properties and clinical application of orthodontic wires vary based on their composition. In this context, it was recommended that achieving favorable outcomes of orthodontic treatment obliges clinicians to decide the best orthodontic wire and treatment plan based on the chemical properties and related clinical applications of each wire. Therefore, wires that tend to produce increasing stiffness gradually are generally used. However, it should be noted that no ideal wire exists. Therefore, favoring the application of a wire over the other should be based on the intended outcomes and stage of the treatment process.

Keywords: Orthodontic wires, Mechanical properties, Orthodontics, Clinical application

INTRODUCTION

Orthodontic treatment is usually conducted by applying forces to certain teeth to move them into a targeted position. Ideal forces can be determined by those that do not damage the periodontal ligament and tooth and produce rapid tooth movement. Unfortunately, evidence shows that orthodontic forces are remarkably variable among the different studies in the literature because it is significantly difficult to accurately estimate the ideal force needed to achieve rapid tooth movement.[1-3] However, some studies reported that lower forces could obtain optimal results. On the other hand, it has been shown that impaired tooth movement might occur secondary to the application of excessive forces, which might decrease cellular activities in periodontal tissues.[4]

Orthodontic wires have been reported to be the primary modalities used in fixed-appliances-based orthodontic treatment to induce favorable tooth movement events.[5] Accordingly, acquiring adequate knowledge about these approaches' clinical applications and biochemical behavior is essential when planning successful orthodontic treatment. Unfortunately, many orthodontic wires were reported with variable biochemical and physical characteristics in the literature.[6,7] Therefore, we conducted a literature review to discuss orthodontic wires' clinical application and mechanical characteristics in the present study.

METHODS

This literature review was based on an extensive literature search in Medline, Cochrane and EMBASE databases on which was performed 3 December 2021 using the medical subject headings (MeSH) or a combination of all possible related terms, according to the database. To avoid missing poetential studies, a further manual search for papers was done through Google Scholar, while the reference lists of the initially included papers. Studies discussing congenital dental anomalies were screened for useful information, with no limitations posed on date, language, age of participants or publication type.

DISCUSSION

Various orthodontic wires were reported among the different studies in the literature. Accordingly, these studies aimed to evaluate their mechanical and physical properties and investigate their clinical efficacy and validity for various sets of orthodontic treatment. Fulfilling all required orthodontic treatment parameters can be best achieved by deciding the most appropriate size and type of orthodontic wires to enhance their clinical significance and raise treatment efficiency. The treatment technique approaches (for instance, straight or segmental wire techniques) can significantly influence the wire sequence during orthodontic treatment. Evidence showed that this process can also be modified when needed based on the treatment requirements. Accordingly, it had been shown that having adequate knowledge about the different mechanical, chemical and physical properties of orthodontic wires can significantly help clinicians choose the most appropriate wires based on geometry, type and size suitable for each case. This can effectively enhance the quality of treatment and enhance the outcomes for the corresponding patients.

Evidence indicated that superelastic NiTi wires were the most commonly used elastic wires during the initial orthodontic treatment process, which were then replaced by stainless-steel and beta-titanium wires during the rest of the treatment process.[8] A previous investigation demonstrated that the amount of activation of stainless steel and Co-Cr wires were usually two and four times the force of beta-titanium and conventional NiTi wires based on the high modulus elasticity of the formerly mentioned wires.[9] It had also been reported that the following equation (strength=stiffness×range) can be significantly used to determine the elastic properties of different orthodontic wires and evaluate their mechanical characteristics.[10] In this context, a linear relationship was found between elastic deformation and force of different orthodontic wires, except for some NiTi conventional wires.[11] Moreover, it had been shown that the length, size and geometry were the main determinants of the different elastic properties of orthodontic wires (range, stiffness and strength).

Evidence indicated that an increase in size significantly increased the stiffness of most conventional wires. But, on the other hand, the working range and flexibility were usually decreased. However, evidence indicated that this did not apply to the multistranded wires, particularly NiTi.[12] For the rest of the orthodontic wires, it had been demonstrated that, regardless of the approached construction material, changes in the shape and size were of the same degree. For instance, it had been observed that the initial stiffness of a stainless wire will be significantly reduced by half when the diameter was also decreased at the same rate.[13] In the same context, the elasticity of these modalities also increased and would be decreased in a proportionate correlation to any increase in length. Moreover, sliding freeing by loosely ligating the wire into the brackets can significantly increase resilience.[14] It can also be noted that severely reduced stiffness and torque control have been associated with rounding the edges of rectangular wires.

Different factors were proposed in the literature as potential parameters that might influence torque control. These included the free space between the bracket slot and the wire, the type of ligation and other factors related to the design of the approached brackets. Previous studies also indicated that the edge bevel, wire section and raw material might also have a significant role in this context.[15-17] However, it had been previously reported that no significant differences were noticed between Cu-Ni-Ti, TMA and stainless steel wires in terms of torque expression by small activations (<12º). However, it should be noted that stainless steel wires had 2.5-3 and 1.5-2 times higher forces than Cu-Ni-Ti and TMA wires in higher angles (>24º), respectively.[18] Studies also showed that the superelasticity expression of NiTi wires was significantly variable. However, it had been shown that it usually ranged around 20º at torsion in mouth temperature. Accordingly, it had been suggested that it was difficult to estimate the clinical characteristics and outcomes of real torsion force and NiTi wire cross-section.[19] In addition to the importance of determining the size increase and proper wire configuration of orthodontic wires, it had been reported that using variable-modulus orthodontics might also enhanced the treatment outcomes.[20] Accordingly, evidence from various laboratory investigations indicated that wires' stiffness and expressed force were proportionally variable.[21,22]

It had been shown that the stiffness correlations of NiTi wires, beta-Ti, SS and Cr-Co were 0.26:0.42:1:1.2. Moreover, a single-strand stainless steel wire's estimated stiffness was 2-4 times higher than that of multistranded wires.[20] Accordingly, clinicians can use bigger wires during orthodontic treatment because of the better 3D control of movements. Besides, controlling the amount of friction can be achieved by establishing a constant relationship between the bracket slot and the wire.[23] However, it had been demonstrated that using wires with higher stiffness and narrower activation ranges was better to control wire actions in areas where movement was not usually anticipated, although some evidence showed that comprehensive working and low stiffness range were favorable characteristics for tooth movement.[24] Therefore, wires with low force delivery and a wide range of activation were recommended during orthodontic treatment.[23] Accordingly, it had been shown that clinicians preferred to use wires with sufficient strength, high resilience and low stiffness.[25] In addition, the initially selected wire should have the maximum tolerated when attached to the maximum activation point.[26] Therefore, it had been suggested that the first wires used during initial orthodontic treatment should be superelastic NiTi wires with a small diameter. Then, other rectangular NiTi wires can be used to provide more stiffness characters during the last steps. In this context, previous research indicated that NiTi wires' high resilience characteristics suggest that a wide range of elastic activation and deformation was usually attainable with using NiTi wires.[9,27,28] Moreover, it had been shown that these modalities also exhibited more and lower constant force when compared to Cr-Co and stainless steel wires.

Many advantages were reported for using NiTi wires during orthodontic treatment. These included high patient comfort levels, faster rotation correction and leveling, reduced chair time and decreased wire changes.[27] However, it had been recommended that firmly fit rectangular wires should not be used during the initial orthodontic treatment steps to avoid the potential reciprocal movement of the treated teeth. This had been reported to increase the risk of root resorption and treatment time potentially. Proffit et al reported that low diameter wires should be used instead during this initial treatment step.[13] This can significantly enhance the potential to simultaneously achieve torque control, rotation correction, alignment and level during orthodontic treatment. For correction incisors overbite (reverse curve of Spee arches or utility arches), using intermediate sizes of Australian wires had been shown to yield favorable outcomes. This had been attributed to the high resilience of these modalities towards plastic deformation powers that were usually exerted by external forces.[9] Accordingly, it had been suggested that when the leveling and alignment of the dental arches were usually approached during orthodontic treatment, wires with increased strength and small diameters should be used during the treatment process.[29,30]

Irrespective of the used wire, clinicians should care for the loose legation of the wires during the initial treatment process to allow for a free-sliding of the wires within the bracket slots. Accordingly, it had been demonstrated that the treatment process can be faster. In addition, in cases of high crowding events, evidence demonstrated that wires with expressable share memory and superelastic NiTi wires should be used to insert the wire in the corresponding brackets because of the large deformation.[31] On the other hand, evidence indicated that superelastic NiTi wires, which were less stiff, should be used for cases with symmetric crowding. Otherwise, it had been demonstrated that the risk of losing dental arch shape would be higher secondary to the alignment of the teeth within the same period. Previous research had further reported that the efficacy of multistranded wires was significant and comparable to the NiTi wires and can replace expensive wires during the initial phase of orthodontic treatment.[13] Furthermore, researchers estimated a wider range of activities for the three-stranded 0.015´´ stainless steel wire than beta-titanium and conventional NiTi wires.[32] On the other hand, previous clinical investigations reported no significant differences in teeth leveling and speed and initial alignment ability between multistranded stainless steel, conventional NiTi and superelastic NiTi wires.[33-36] Moreover, bonding various biomechanic accessories and proper wire bending was essential during the initial orthodontic treatment process. When approaching complex configuration management, it had been shown that beta-titanium wires were good candidates for these events. This had been attributed to the non-solder-based weldability and the enhanced forming behavior. However, they have a very high cost, which might affect their clinical use and application. In the same context, studies also demonstrated that these modalities were usually associated with lower forces and a wider range of activation more than the Co-Cr and stainless steel wires.[23,26,37]

Inserting NiTi wires with large cut sections can be used when there was no requirement for wire bending.[23] In these events, evidence showed that stainless steel wires can effectively induce sliding with movement-associated low friction characteristics.[23,37] Furthermore, previous laboratory-based investigations on wire notching-based permanent deformations (which temporarily block movement) and wire bindings that occured at the initial phases of treatment were critical to achieving enhanced treatment outcomes.[38-41] Accordingly, it had been suggested that the process of tooth movement during this setting was multifactorial and cannot be adequately comprehended by simple laboratory investigations, indicating the need for clinical investigations.[41,42] Accordingly, it had been shown that the clinical significance of studies showing that stainless steel wires were superior to Ti-alloy was minimal. However, many clinicians should note that stainless steel wires favorably have better torque control, greater stability and subsequent smaller movement events. On the other hand, studies also showed that beta-titanium wires should be used for larger corrections. This had been attributed to the ability of these modalities to intervene against enduring excessive forces on the teeth because of their greater range of activation. Finally, evidence showed that NiTi wires were unsuitable for final orthodontic treatment stages because of their low stiffness abilities.[23,26,30,37,43-46]

CONCLUSION

Orthodontic wires are widely used and are mainly composed of composites, polymers, alloys, and metals. Accordingly, the physical properties and clinical application of orthodontic wires vary based on their composition. In this context, it is recommended that achieving favorable outcomes of orthodontic treatment obliges clinicians to decide the best orthodontic wire and treatment plan based on the chemical properties and related clinical applications of each wire. Therefore, wires that tend to produce increasing stiffness gradually are generally used. However, it should be noted that no ideal wire exists. Therefore, favoring the application of a wire over the other should be based on the intended outcomes and stage of the treatment process.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Houston WJB, Stephens C, Tulley WJ, Foster M. A textbook of orthodontics. Wright Publishers; 1992.
2. Shetty V, Caridad JM, Caputo AA, Chaconas SJ. Biomechanical rationale for surgical-orthodontic expansion of the adult maxilla. J Oral Maxillofac Surg. 1994;52(7):742-9.
3. Holberg C, Holberg N, Rudzki-Janson I. Sutural strain in orthopedic headgear therapy: a finite element analysis. Am J Orthodont Dentofac Orthoped. 2008;134(1):53-9.
4. Leach HA, Ireland AJ, Whaites EJ. Radiographic diagnosis of root resorption in relation to orthodontics. Brit Dent J. 2001;190(1):16-22.
5. Rudolph DJ, Willes PMG, Sameshima GT. A finite element model of apical force distribution from orthodontic tooth movement. Angle Orthodont. 2001;71(2):127-31.
6. Mistakidis I, Gkantidis N. Review of properties and clinical applications of orthodontic wires. Hell Orthod Rev. 2011;14:45-66.
7. Sharmila R. Wires in orthodontics-a short review. J Pharmaceut Sci Res. 2016;8(8):895-7.
8. Keim RG, Gottlieb EL, Nelson AH, Vogels DS. 2002 JCO study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends. J Clin Orthodont. 2002;36(10):553-68.
9. Drake SR, Wayne DM, Powers JM, Asgar K. Mechanical properties of orthodontic wires in tension, bending, and torsion. Am J Orthodont. 1982;82(3):206-10.
10. Kusy RP, Greenberg AR. Effects of composition and cross section on the elastic properties of orthodontic wires. Angle Orthodont. 1981;51(4):325-41.
11. Zufall SW, Kusy RP. Stress relaxation and recovery behaviour of composite orthodontic archwires in bending. Eur J Orthodont. 2000;22(1):1-12.
12. Ingram SB, Gipe DP, Smith RJ. Comparative range of orthodontic wires. Am J Orthodont Dentofac Orthoped. 1986;90(4):296-307.
13. Proffit WR, Fields HW, Larson B, Sarver DM. Contemporary orthodontics-e-book. Elsevier Health Sciences; 2018.
14. Adams DM, Powers JM, Asgar K. Effects of brackets and ties on stiffness of an arch wire. Am J Orthodont Dentofac Orthoped. 1987;91(2):131-6.
15. Sebanc J, Brantley WA, Pincsak JJ, Conover JP. Variability of effective root torque as a function of edge bevel on orthodontic arch wires. Am J Orthodont. 1984;86(1):43-51.
16. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. Am J Orthodont Dentofac Orthoped. 2004;125(3):323-8.
17. Morina E, Eliades T, Pandis N, Jäger A, Bourauel C. Torque expression of self-ligating brackets compared with conventional metallic, ceramic, and plastic brackets. Eur J Orthodont. 2008;30(3):233-8.
18. Archambault A, Major TW, Carey JP, Heo G, Badawi H, Major PW. A comparison of torque expression between stainless steel, titanium molybdenum alloy, and copper nickel titanium wires in metallic self-ligating brackets. Angle Orthodont. 2010;80(5):884-9.
19. Partowi S, Keilig L, Reimann S, Jäger A, Bourauel C. Experimental analysis of torque characteristics of orthodontic wires. J Orofac Orthoped. 2010;71(5):362-72.
20. Burstone CJ. Variable-modulus orthodontics. Am J Orthodont. 1981;80(1):1-16.
21. Rucker BK, Kusy RP. Elastic flexural properties of multistranded stainless steel versus conventional nickel titanium archwires. Angle Orthodont. 2002;72(4):302-9.
22. Garrec P, Tavernier B, Jordan L. Evolution of flexural rigidity according to the cross-sectional dimension of a superelastic nickel titanium orthodontic wire. Eur J Orthodont. 2005;27(4):402-7.
23. Kusy RP. A review of contemporary archwires: their properties and characteristics. Angle Orthodont. 1997;67(3):197-207.
24. Burstone CJ, Qin B, Morton JY. Chinese NiTi wire--a new orthodontic alloy. Am J Orthodont. 1985;87(6):445-52.

25. Rucker BK, Kusy RP. Elastic properties of alternative versus single-stranded leveling archwires. Am J Orthodont Dentofac Orthoped. 2002;122(5):528-41.
26. Johnson E. Relative stiffness of beta titanium archwires. Angle Orthodont. 2003;73(3):259-69.
27. Andreasen GF, Morrow RE. Laboratory and clinical analyses of nitinol wire. Am J Orthodont. 1978;73(2):142-51.
28. Oliver RG. Orthodontic materials. Scientific and clinical aspects. J Orthodont. 2002;29(1):75.
29. Verstrynge A, Humbeeck J, Willems G. In-vitro evaluation of the material characteristics of stainless steel and beta-titanium orthodontic wires. Am J Orthodont Dentofac Orthoped. 2006;130(4):460-70.
30. Krishnan V, Kumar KJ. Weld characteristics of orthodontic archwire materials. Angle Orthodont. 2004;74(4):533-8.
31. Bartzela TN, Senn C, Wichelhaus A. Load-deflection characteristics of superelastic nickel-titanium wires. Angle Orthodont. 2007;77(6):991-8.
32. Kusy RP, Stevens LE. Triple-stranded stainless steel wires--evaluation of mechanical properties and comparison with titanium alloy alternatives. Angle Orthodont. 1987;57(1):18-32.
33. Evans TJ, Jones ML, Newcombe RG. Clinical comparison and performance perspective of three aligning arch wires. Am J Orthodont Dentofac Orthoped. 1998;114(1):32-9.
34. West AE, Jones ML, Newcombe RG. Multiflex versus superelastic: a randomized clinical trial of the tooth alignment ability of initial arch wires. Am J Orthodont Dentofac Orthoped. 1995;108(5):464-71.
35. Wang Y, Jian F, Lai W. Initial arch wires for alignment of crooked teeth with fixed orthodontic braces. Cochrane Database Systemat Rev. 2010;4:7859.
36. Riley M, Bearn DR. A systematic review of clinical trials of aligning archwires. J Orthodont. 2009;36(1):42-51.
37. Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires. Am J Orthodont Dentofac Orthoped. 1989;96(2):100-9.
38. Thorstenson GA, Kusy RP. Effect of archwire size and material on the resistance to sliding of self-ligating brackets with second-order angulation in the dry state. Am J Orthodont Dentofac Orthoped. 2002;122(3):295-305.
39. Hamdan A, Rock P. The effect of different combinations of tip and torque on archwire/bracket friction. Eur J Orthodont. 2008;30(5):508-14.
40. Articolo LC, Kusy K, Saunders CR, Kusy RP. Influence of ceramic and stainless steel brackets on the notching of archwires during clinical treatment. Eur J Orthodont. 2000;22(4):409-25.
41. Burrow SJ. Friction and resistance to sliding in orthodontics: a critical review. Am J Orthodont Dentofac Orthoped. 2009;135(4):442-7.
42. Swartz ML. Fact or friction: the clinical relevance of in vitro steady-state friction studies. J Clin Orthodont. 2007;41(8):427-32.
43. Kusy RP, Mims L, Whitley JQ. Mechanical characteristics of various tempers of as-received cobalt-chromium archwires. Am J Orthodont Dentofac Orthoped. 2001;119(3):274-91.
44. Kapila S, Angolkar PV, Duncanson MG, Nanda RS. Evaluation of friction between edgewise stainless steel brackets and orthodontic wires of four alloys. Am J Orthodont Dentofac Orthoped. 1990;98(2):117-26.
45. Krishnan V, Kumar KJ. Mechanical properties and surface characteristics of three archwire alloys. Angle Orthodont. 2004;74(6):825-31.
46. Cash A, Curtis R, Garrigia-Majo D, McDonald F. A comparative study of the static and kinetic frictional resistance of titanium molybdenum alloy archwires in stainless steel brackets. Eur J Orthodont. 2004;26(1):105-11.

Cite this article as: MA, Nassir MAA, Nayas LM, Alabdulkarim MN, Faden FY, Alghamlas AS, et al. Mechanical properties and clinical significance of orthodontic wires. Int J Community Med Public Health 2022;9:932-6.