Evaluation of torque moment in a novel elastic bendable orthodontic wire

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INTRODUCTION

In modern orthodontics, several kinds of alloy wires have been provided and used for various applications depending on its purpose. Nickel-titanium (Ni-Ti) wires are suitable for initial leveling and alignment with multi-bracket appliances since they have unique property of superelasticity and a good springback. On the other hand, they are preferable for neither wire bending nor torque application, which means they are not suitable as a wire for the finishing and detailing phase. Stainless steel (SS) wires have remained popular since their introduction to orthodontics because of their formability, biocompatibility and environmental stability, stiffness, resilience, and low cost. They are useful for every step of multi-bracket treatment, leveling, space closure, and finishing and detailing; however, they have less elasticity. In the past quarter century, Titanium-molybdenum (Ti-Mo) wires having characteristics of Ni-Ti and SS wires came on the stage. The alloys consist of Group IVa and Va elements and oxygen. The composition is Ti-23Nb-0.7Ta-2Zr-O (mole percent [mol%]) wherein each alloy has a simple body-centered cubic crystal structure, and the wire simultaneously offers superelasticity, super strength, super cold workability, and invar and elinvar properties. Titanium is well known to its good mechanical properties, its high corrosion resistance, and its excellent biocompatibility. Niobium has been reported to have good cytocompatibility and biocompatibility in both in vitro and in vivo experiments. Additionally, the alloy does not contain Ni which is one of the most common metals to evoke the metal allergy. These indicate that the novel alloy might satisfy suitable properties as an orthodontic wire. This alloy was recently marketed for the purpose of orthodontic use (Ti-Nb alloy, Gummetal, RMMC Inc., Tokyo, Japan). However, the features of Ti-Nb alloy as an orthodontic wire have been still unknown.

In clinical orthodontics, torque expression is one of the important determinants for treatment outcome. In particular, correct buccolingual inclination of the anterior teeth is essential for providing acceptable occlusal relationships. Torque expression can be achieved by filling the bracket slot and gradually increasing the wire dimensions during orthodontic treatment. Therefore, until the slot fills the wire, a considerable percentage of the torque built into the bracket is lost because of the play between the wire and bracket slot. There are a number of reports in the literature in which the theoretical and/or measured torque moments between wire and bracket have been calculated. Although there may be some discrepancies between in vitro and in vivo conditions, these studies could help in understanding the amount of third-order bends for wire-bracket-ligation combinations.

The objective of this study is to measure the torque moment delivered by a novel elastic orthodontic wire, Ti-Nb, and to compare it with nickel-titanium (Ni-Ti) and titanium-molybdenum (Ti-Mo) alloys. Two sizes of Ti-Nb, Ni-Ti and Ti-Mo alloy wires and 0.022-inch slot stainless steel brackets were ligated with elastic modules or ligature wires. The torque moment delivered by the various wire-bracket combinations was measured using a torque gauge at the temperature and humidity of 37°C and 50%, respectively. As the degree of applied torque and the inserted wire size increased, the torque moment gradually increased. The torque moment of Ti-Nb wires was smaller than those of Ni-Ti wires and Ti-Mo wires, at more than 20 degrees applied torque. The torque moment with wire ligation was significantly larger than those with elastic ligation.

Keywords: Torque moment, Orthodontic wire, Ti-Nb
Fig. 1 (a) The torque testing apparatus consisted of a torque transducer connected to a torque gauge. The black arrow indicated part of bracket and wire for measurement, the white arrow head showed the torque transducer and the black arrow head demonstrated the circular protractor to measure torque moment. (b) High magnification of the bracket and wire part. The simulated lateral incisor on the central rod was rotatable (black arrow), and another two brackets were fixed on the base (white arrows).

The measuring apparatus consisted of a torque transducer connected to a torque gauge (Kyowa Electronic Instruments Co., Tokyo, Japan; Fig. 1a). The simulated twin SS brackets (Super mesh standard edgewise bracket; Tomy International Inc., Tokyo, Japan) for central incisor (bracket width: 3.2 mm), lateral incisor (2.6 mm), and canine (2.6 mm) with a 0.022×0.028 inch slot were placed on one side and a circular protractor to measure torque moment on the other (Fig. 1b). The simulated lateral incisor on the central rod was rotatable and the other two brackets were fixed on the base. The brackets were positioned in the same line of the slot to the wire, i.e. 0 degree angulation and 0 moments. The interbracket distance was determined to be 6 mm. To align and set the brackets, a full size SS wire was used. The torque moment was measured with wire ligation (0.010 inch ligature wire; Tomy International Inc.) or elastic module ligation (Las-Tie; Tomy International Inc.). During measurements, the temperature and humidity were kept constant at 37°C and 50%, respectively. Five bracket sets were prepared and the measurement of torque moment was performed 15 times for each bracket-wire combination. Means of the measurement values were used as proper data.

The data were statistically analyzed using the Statistical Package for Social Sciences (Version 8.0 for Windows; SPSS Japan Inc., Tokyo, Japan). The data showed normal distribution and statistical analysis was performed using analysis of variance multiple comparison tests and post hoc Turkey’s honestly significant difference test or Mann-Whitney U test. A probability of \( p < 0.05 \) was considered significant.

RESULTS

Comparison among the three wires (Figs. 2 and 3, Tables 1 and 2)
The moments of the 0.017×0.025 inch Ti-Nb wires with wire ligation were smaller than those of Ni-Ti wires at 10 to 40 degree torque applications, which were 85 to 89 percent. In comparison with the Ti-Mo wires, the 0.017×0.025 inch Ti-Nb wires with wire ligation showed significantly smaller torques of 77 to 88 percent at more than 15 degrees of applied torques.

The moments of the 0.017×0.025 inch Ti-Nb wires ligated with an elastic ligature were smaller than those of Ni-Ti wires at 15 to 40 degree torque applications, which were 78 to 91 percent. With more than 15 degrees of applied torque, the moments of the 0.017×0.025 inch Ti-Nb wires with elastic ligation showed approximately 72 to 92 percent of those of Ti-Mo wires, which were statistically significant.

At 10 to 40 degrees, the moments of 0.019×0.025 inch Ti-Nb wires with wire ligation were smaller than those of Ni-Ti wires, which were 73 to 95 percent. The moments of 0.019×0.025 inch Ti-Nb wires with a ligature wire were significantly smaller than those of Ti-Mo wires at all applied torques, which were 59 to 86 percent.

At 20 to 40 degrees, the moments of 0.019×0.025 inch Ti-Nb wires with module ligation were smaller than those of Ni-Ti wires, which were 72 to 84 percent. With the applied torque of more than 10 degree, the moments of 0.019×0.025 inch Ti-Nb wires with an elastic module were significantly smaller than those of Ti-Mo wires, which were 56 to 90 percent.
Comparison between wire and elastic ligation (Figs. 2 and 3, Tables 1 and 3)
For the 0.017×0.025 inch Ti-Nb wires, the moments with wire ligation were 1.2 to 1.3 times larger than those with elastic ligation. The moments with wire ligation in the 0.017×0.025 inch Ni-Ti and Ti-Mo wires were 1.1 to 1.4 times larger than those with elastic ligation. The moment of the 0.019×0.025 inch Ti-Nb wires with wire ligation was approximately 1.1 to 1.4 times larger than that with elastic ligation. The 0.019×0.025 Ni-Ti and Ti-Mo wires with wire ligation also showed 1.1 to 1.5 times larger torque moment than those with elastic ligation. For all the wires, the torque moment with wire ligation was significantly larger than those with elastic ligation.

DISCUSSION
The desirable characteristics in an orthodontic wire are a large springback, low stiffness, good formability, high stored energy, bio-compatibility and environmental stability, and low surface friction\(^3\). Several alloy
Table 2  Comparison of torque moments between Ti-Nb versus Ni-Ti or Ti-Mo wires.

| Wire size | Wire material | Ligation          | 5     | 10   | 15   | 20   | 25   | 30   | 35   | 40   |
|-----------|---------------|-------------------|-------|------|------|------|------|------|------|------|
|           | vs Ni-Ti      | Wire              | NS    | *    | *    | *    | *    | *    | *    | *    |
| 0.017×0.025|               | Elastic module    | NS    | NS   | *    | *    | *    | *    | *    | *    |
|           | vs Ti-Mo      | Wire              | NS    | NS   | NS   | *    | *    | *    | *    | *    |
|           |               | Elastic module    | NS    | NS   | NS   | NS   | *    | *    | *    | *    |

Table 3  Comparison of torque moments according to type of ligation (wire vs elastic module).

| Wire size | Wire Material | Significance |
|-----------|---------------|--------------|
| 0.017×0.025| Ti-Nb         | *            |
|           | Ni-Ti         | *            |
|           | Ti-Mo         | *            |
| 0.019×0.025| Ti-Nb         | *            |
|           | Ni-Ti         | *            |
|           | Ti-Mo         | *            |

*p<0.05.

wires, i.e. SS, cobalt-chrome, Ni-Ti and Ti-Mo wires, have been proposed and still commonly used for more than decades. Most orthodontists use several kinds of those alloy wires during the treatment depending on its purpose because no orthodontic wires have completely covered all eligible characteristics.

Ti-Nb wires showed smaller moment torques compared with Ni-Ti wires at applied degrees of more than 10 with wire ligation and 20 with elastic module ligation, but the differences were relatively small. In contrast, Ti-Nb wires showed significantly smaller moment torques compared with Ti-Mo wires at more than 15 applied degrees. Especially, the 0.019×0.025 inch wires at 35 and 40 applied degrees showed greater differences between the Ti-Nb and Ti-Mo wires. These suggest that Ti-Nb wires are more close to the Ni-Ti wires compared with Ti-Mo wires as for the torque moment.

The ligation method completely affected the torque moment. The moment with wire ligation was significantly larger than those with elastic ligation at all applied torques in all wire sizes and materials. These results are consistent with previous studies on this issue.15-17 Except for the ligation methods, several factors associated with torque moment are suggested, i.e. wire stiffness, play between the wire and bracket, bracket design, bracket material and so on.15-20 In the present study, large size wires (0.019×0.025 inch wire) showed larger torque moment than small size wires (0.017×0.025 inch wire), because of the play. However; our findings might provide useful information for clinicians to select the proper ligation method and produce desired torque moment when using these three alloy wires.

Reitan11 suggested that a torqueing movement performed with a 0.021×0.025 inch edgewise arch exerting a force at the root apex of about 130 g could produce histologic changes without any hyalinized areas. The average upper incisor root length is 13.0 mm.21 Thus, it was hypothesized that the optimum torque was approximately 0.01–0.02 Nm, which was basically calculated by data from previous studies.12-15,22,23 Concerning the active moment of optimum torques of the Ti-Nb wires, the hypothesized optimum torques were provided by twisting the 0.017×0.025 inch wires with 15 to 35 degrees with wire ligation and 20 to 40 degrees with elastic module ligation. With the 0.019×0.025 inch wires, the optimal torques were given by twisting with 10 to 30 degrees with wire ligation and 20 to 35 degrees with elastic module ligation. On the contrary, most of the torque prescriptions in contemporary preadjusted edgewise appliances are in the range of –35 to +25 degrees.24 Therefore, the torque moments provided by the twisting of these two sizes of Ti-Nb wires were almost included in the optimal range. It means Ti-Nb wires demonstrate appropriate torque moment when they are used as orthodontic archwires for edgewise appliances.

CONCLUSION

The new orthodontic wire which consists of Ti-Nb alloy has unique torque moment characteristics. The torque moments of Ti-Nb wires were smaller than those of Ti-Mo and Ni-Ti wires when applied torque was larger than 20 degrees. The torque moment with wire ligation was significantly larger than those with elastic ligation.
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