

Magnetic evaluation of orthodontic stainless-steel retainers using an ISO 13017:2020–based measurement system

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I. Introduction

Stainless-steel multistranded wires used for fixed lingual retainers are a well-established retention modality with long-term stability and remain widely employed for maintaining mandibular anterior alignment. Due to their multistranded construction, they offer both flexibility and resistance to fracture, resulting in high mechanical durability and clinical reliability. For these reasons, multistranded stainless-steel wires are regarded as the gold standard among fixed retention devices.^{1,2)}

In recent years, however, stainless-steel retainers have been reported to generate metal-related artifacts derived from magnetization, drawing attention to their behavior under magnetic fields.^{3,4)} With the increasing clinical use of dental magnetic attachments, understanding the magnetic properties of metallic materials placed in the oral cavity has become increasingly important. When stainless-steel retainers possess magnetization, they can distort local magnetic fields and generate signal voids or geometric distortion artifacts in magnetic resonance imaging (MRI), suggesting that the magnetic state of metallic materials may influence diagnostic imaging.^{5,6)}

An intriguing feature of stainless-steel retainers is that the degree of magnetization may vary among samples even when their nominal alloy compositions are identical. Although austenitic 304 stainless steel is inherently non-magnetic, severe plastic deformation during processes such as wire drawing and twisting can induce austenite-to-martensite transformation and confer ferromagnetic behavior.^{7,8,9)} Thus, the magnetization observed in stainless-steel retainers may arise not only from alloy composition but also from processing history.

Moreover, previous studies have reported that omega loops in stainless-steel orthodontic archwires may undergo martensitic transformation in the oral environment.¹⁰⁾ Because stainless-steel retainers are routinely bent to fit the dental arch prior to bonding, such bending may induce additional deformation-related martensitic transformation in the wire. The extent and manner of this bending manipulation are operator-dependent, and thus any changes in magnetic properties induced by bending could introduce an operator-dependent factor with potential clinical implications. Nevertheless, quantitative information on the magnetization of stainless-steel multistranded wires remains scarce, and the effects of routine clinical bending manipulations on magnetic attraction force have not been elucidated.

II. Objective

The aim of this study was to quantitatively assess the magnetization of stainless-steel multistranded wires using an ISO 13017:2020-compliant measurement system. As stainless-steel retainers may cause MRI-related artifacts and their magnetic properties could depend on processing history, it is important to determine whether routine chairside bending contributes to magnetization. Therefore, this study examined whether the bending procedures used during fabrication of fixed lingual retainers alter magnetic attraction force.

III. Materials and Methods

1 Wire specimens

Two types of stainless-steel multistranded wires commonly used for fixed lingual retainers were tested: 0.0175-inch and 0.0195-inch (TOMY, Tokyo, Japan). Each specimen was cut into 20-mm segments for measurements.

2 Measurement system

Magnetic attraction force was evaluated using a measurement system compliant with ISO 13017:2020¹¹⁾, which specifies test methods for magnetic attraction force in dental magnetic attachments (Fig. 1A). A digital force gauge (ZPS, Imada, Aichi, Japan) and a magnetic attachment (Physio Magnet 5213; Morita, Tokyo, Japan; 5.2 mm diameter, 1.3 mm height) were used as the force sensor and magnetic field source, respectively. The magnetic attachment was chosen because its closed magnetic circuit provides stable magnetic flux density with minimal magnetic field leakage, enabling accurate evaluation of magnetization.^{12,13)}

3 Measurement procedure

The wire specimen was fixed to the lower movable stage and the magnetic attachment to the upper stage with its mating surface facing downward. Starting from direct contact between the attachment and the wire, the lower stage was moved vertically at a crosshead speed of 2.0 mm/min, and the maximum load during separation was defined as the magnetic attraction force.

4 Bending conditions

To evaluate the effect of clinical bending manipulations, measurements were performed under four conditions (Fig. 1B):

- Condition 1: No bending
- Condition 2: One-point bending
- Condition 3: Two-point bending
- Condition 4: Two-point bending followed by straightening

5 Data acquisition and analysis

For each wire type, three specimens were tested, and five repeated measurements per specimen were obtained; the mean value was used for analysis. Differences in magnetic attraction force among the four conditions were evaluated using one-way analysis of variance (ANOVA). Statistical analyses were conducted using JMP 19 (SAS Institute Inc., Cary, NC, USA), with the significance level set at 5%.

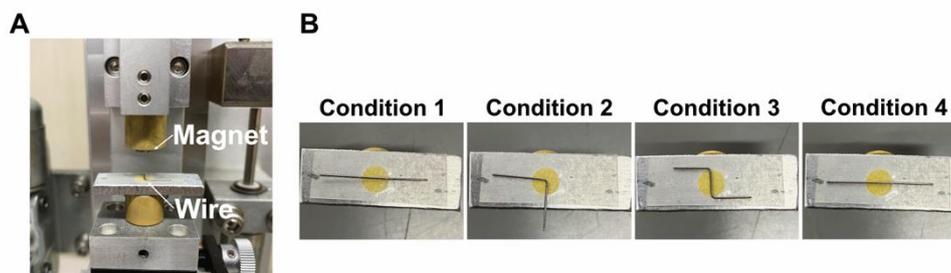


Figure 1. Magnetic attraction force testing of wires using an ISO 13017:2020-based measurement system.

IV. Results

Magnetic attraction measurements confirmed measurable magnetization in both multistranded wire types (Fig. 2). The 0.0175-inch wire exhibited approximately 0.04 N of magnetic attraction under all four bending conditions, whereas the 0.0195-inch wire demonstrated slightly higher values at approximately 0.05 N. Thus, a subtle difference in magnetization was observed between the two wire types. Notably, for each wire type, no statistically significant differences were detected among the No bending, One-point bending, Two-point bending, and Two-point bending followed by straightening conditions (all n.s.). These findings indicate that routine clinical bending manipulations do not increase magnetic attraction force and do not enhance magnetization.

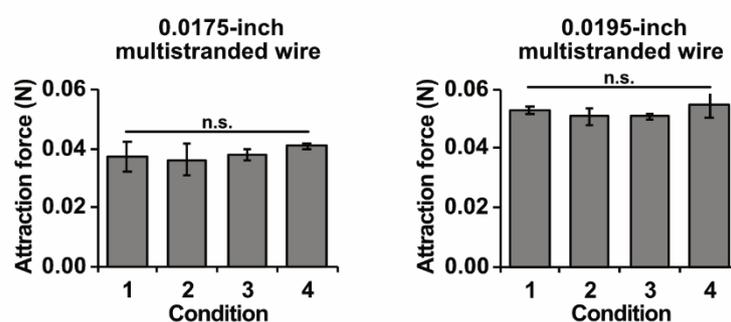


Figure 2. Magnetic attraction force measurements of the stainless-steel multistranded wires.

V. Discussions

In this study, the magnetic properties of stainless-steel multistranded wires were quantitatively evaluated by measuring magnetic attraction force using a magnetic attachment compliant with ISO 13017. The results demonstrated that both the 0.0175-inch and 0.0195-inch wires exhibited distinct magnetization, indicating that stainless-steel multistranded wires commonly used for fixed lingual retainers possess clinically non-negligible magnetic properties. Although austenitic 304 stainless steel is intrinsically non-magnetic, severe plastic deformation during wire drawing and twisting is known to induce martensitic transformation.^{7,8,9)} The present findings likely reflect such processing-induced martensite formation.

The use of a magnetic attachment as the magnetic field source enabled measurements under a closed magnetic circuit with a stable magnetic flux distribution. Because magnetic attachments exhibit limited leakage flux and provide highly reproducible magnetic field distributions, they proved effective for precise quantitative evaluation of the magnetic response of stainless-steel wires. Compared with previously reported methods employing permanent magnets, this measurement system offers substantially improved magnetic field stability and is better suited for detecting differences in magnetization arising from wire structure and processing history. Given that magnetic attachments are widely used as clinical devices, the methodology adopted in this study can be regarded as a technically valid and clinically relevant evaluation tool within the field of magnetic dentistry.

Importantly, analysis of the influence of bending manipulations—an essential clinical procedure during retainer fabrication—revealed that no significant differences in magnetic attraction force were observed among the no bending, one-point bending, two-point bending, and two-point bending followed by straightening conditions. In other words, routine chairside adjustments did not enhance magnetization and did not introduce additional magnetization to the wire. A plausible explanation is that prior to bending, substantial deformation-induced martensitic transformation may have already occurred during the wire drawing and twisting processes, such that routine clinical bending induces

insufficient additional plastic strain to promote further transformation.^{8,9)} Put differently, processing-induced martensitic stainless steel may have reached a stage at which further enhancement of magnetization does not occur with ordinary chairside adjustments.

These findings bear clinically relevant implications for the use of fixed lingual retainers. Orthodontists can perform fine bending adjustments to adapt the wire to the dental arch without concern that such manipulations will increase magnetization or cause unexpected effects when magnetic devices are used. Furthermore, the fact that magnetization appears to be largely determined during manufacturing rather than by operator-dependent manipulation offers practical advantages for material selection and device design.

Taken together, stainless-steel multistranded wires used for fixed lingual retention acquire magnetization through processing-induced martensite formation during manufacturing, whereas typical clinical adjustments do not further increase magnetization. The results of this study provide foundational information relevant to the selection and optimization of materials and manufacturing conditions for fixed retainers, and may inform future research and clinical applications involving magnetic devices in the field of magnetic dentistry.

VI. Conclusions

Stainless-steel multistranded retainers demonstrated measurable magnetization, but routine chairside bending did not increase magnetic attraction force. This indicates that magnetization is largely defined during manufacturing and is not affected by the clinical adjustments required for retainer fabrication. These results provide practical reassurance that orthodontists can adapt retainers to the dental arch without altering their magnetic behavior and offer valuable information for future material development and clinical use involving magnetic devices.

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