Comparison of Autoclave and Hot Air Oven Sterilization on Bending Properties of NiTi Wires

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**Abstract:** Sterilization is a critical process in dental and orthodontic practice to eliminate microbial contamination and ensure patient safety. This study aims to evaluate and compare the effects of autoclave and hot air oven sterilization on the load-deflection properties of nickel-titanium (NiTi) wires, which are widely used in orthodontics due to their superelastic properties. Three groups of straight NiTi wires with diameters of 0.016 × 0.022 inch, 0.021 × 0.028 inch, and 0.7 mm were tested. Each sample was sterilized using an autoclave and a hot air oven. The bending properties of the wires were assessed using a three-point bending test conducted on an Instron universal testing machine at a cross-head speed of 1 mm/min. The load-deflection values were recorded and analyzed to determine changes in elasticity, flexibility, and overall mechanical integrity post-sterilization. Results indicated that autoclave sterilization caused a greater reduction in flexibility compared to hot air oven sterilization. Hot air oven sterilization showed less degradation in the superelastic properties of NiTi wires, suggesting that it may be a more suitable sterilization method for maintaining wire performance. The study concludes that while both methods effectively sterilize NiTi wires, hot air oven sterilization preserves the mechanical integrity of NiTi wires more effectively than autoclave sterilization.

**Keywords:** Autoclave Sterilization, Autoclave Sterilization, uperelasticity, Evaluation of cytocompatibility, superelastic properties

# INTRODUCTION

Sterilization is essential in dental and orthodontic practice to prevent cross-contamination and maintain patient safety [(Deepika et al., 2022; Harsha & Subramanian, 2022; Solanki et al., 2022)](https://paperpile.com/c/qsEttd/Rc7cM+wriKi+8W4Rq). It is defined as the process of eliminating(Rafi et al., 2024), deactivating, or killing all forms of microbial life, including bacteria, viruses, fungi, and spores, on surfaces or instruments (Tuluwengjiang et al., 2024). Sterilization differs from disinfection and sanitization, which only reduce microbial load but do not eliminate all microorganisms [(Andersen, 2019; McDonnell & Russell, 1999; Rutala, 2005)](https://paperpile.com/c/qsEttd/62TI+B7H1+nvbX).

Orthodontic appliances, including nickel-titanium (NiTi) wires, are frequently reused, necessitating reliable sterilization techniques to ensure clinical safety without compromising the mechanical properties of the wires [(Duerig et al., 2013)](https://paperpile.com/c/qsEttd/yFcH). NiTi wires are widely used in orthodontics due to their superelasticity, shape memory effect, and corrosion resistance, which facilitate effective tooth movement and enhance patient comfort [(Duerig et al., 2013; Yoneyama & Miyazaki, 2008)](https://paperpile.com/c/qsEttd/yFcH+glGr).

## Two commonly used sterilization methods in dental practice are autoclave and hot air oven sterilization

* **Autoclave Sterilization:** Autoclaving involves high-pressure saturated steam at temperatures ranging from 121°C to 134°C. It is highly effective in eliminating microbes but may cause structural changes in NiTi wires due to exposure to moisture and high temperatures [(Ajay, Rakshagan, et al., 2022; Ajay, Sasikala, et al., 2022; Chidambaram et al., 2022)](https://paperpile.com/c/qsEttd/cnNut+yw55C+Pqe60).
* **Hot Air Oven Sterilization:** Hot air ovens use dry heat at temperatures between 160°C and 180°C for a specific period. While this method avoids moisture exposure, the high temperatures may still affect the mechanical properties of NiTi wires [(Ajay, Suma, et al., 2022; Katyal et al., 2021; Maiti, 2021)](https://paperpile.com/c/qsEttd/Pjs9D+3cSpw+i4Qcl).  
  NiTi wires have been continuously modified since their introduction to the orthodontic market over 30 years ago to improve their flexibility and resilience [(Brantley & Eliades, 2011; Duerig et al., 2013; Yoneyama & Miyazaki, 2008)](https://paperpile.com/c/qsEttd/yFcH+glGr+D61g). Studies have shown that mechanical properties such as flexibility and elasticity are sensitive to thermal and environmental changes during sterilization[(Gibson et al., 2014)](https://paperpile.com/c/qsEttd/E9At).

This study aims to compare the effects of autoclave and hot air oven sterilization on the bending properties of NiTi wires to determine which method better preserves their superelastic properties.

# MATERIALS AND METHODS

A laboratory-based experimental design was followed to assess the effect of sterilization on the bending properties of NiTi wires.

Three groups of straight NiTi wires were tested:

* 0.016 × 0.022 inch
* 0.021 × 0.028 inch
* 0.7 mm diameter

Each wire sample was cut into 30 mm segments.

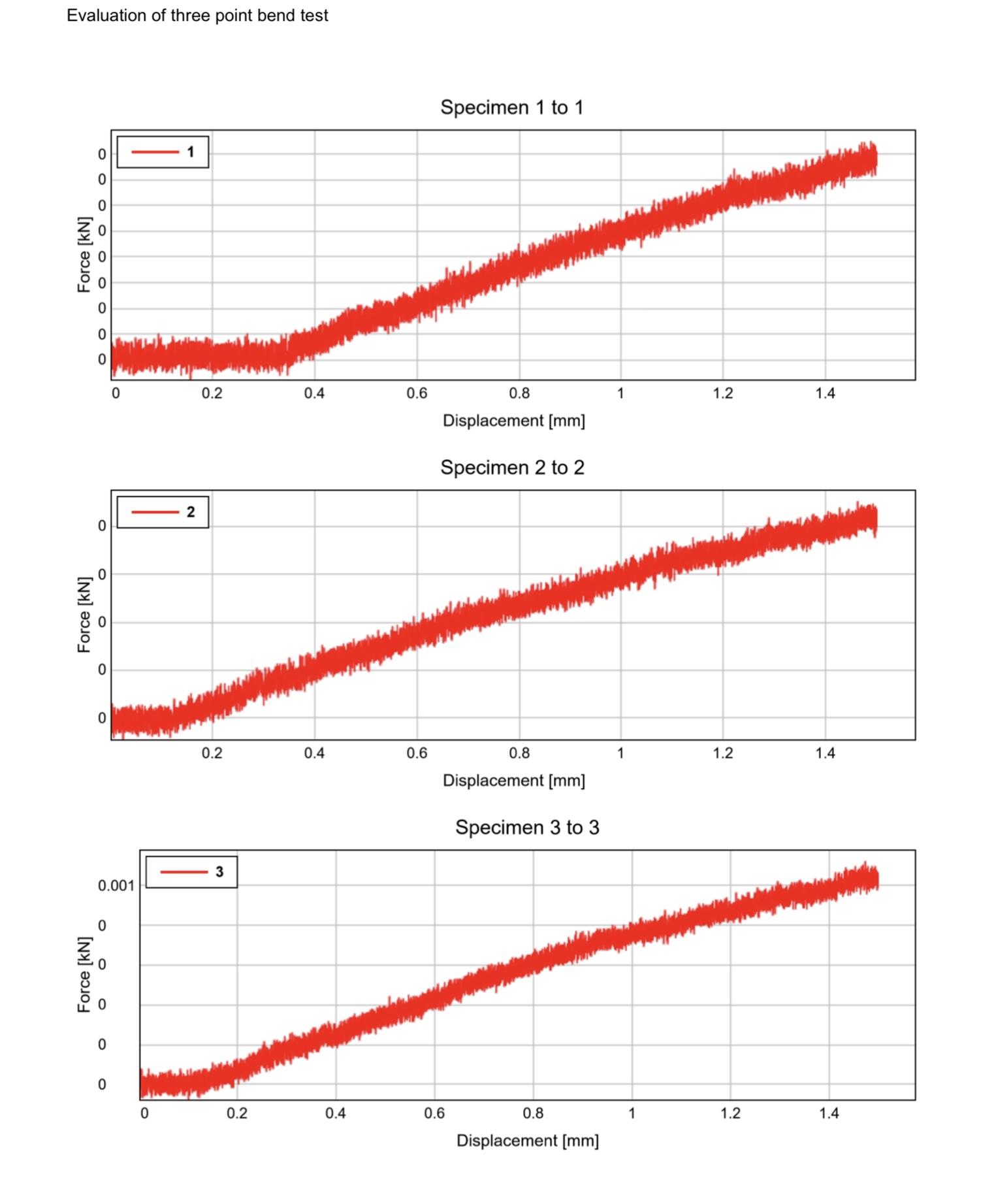
## Sterilization Process

* **Group 1:** Sterilized using an autoclave at 121°C for 15 minutes under 15 psi pressure.
* **Group 2:** Sterilized using a hot air oven at 160°C for 1 hour.

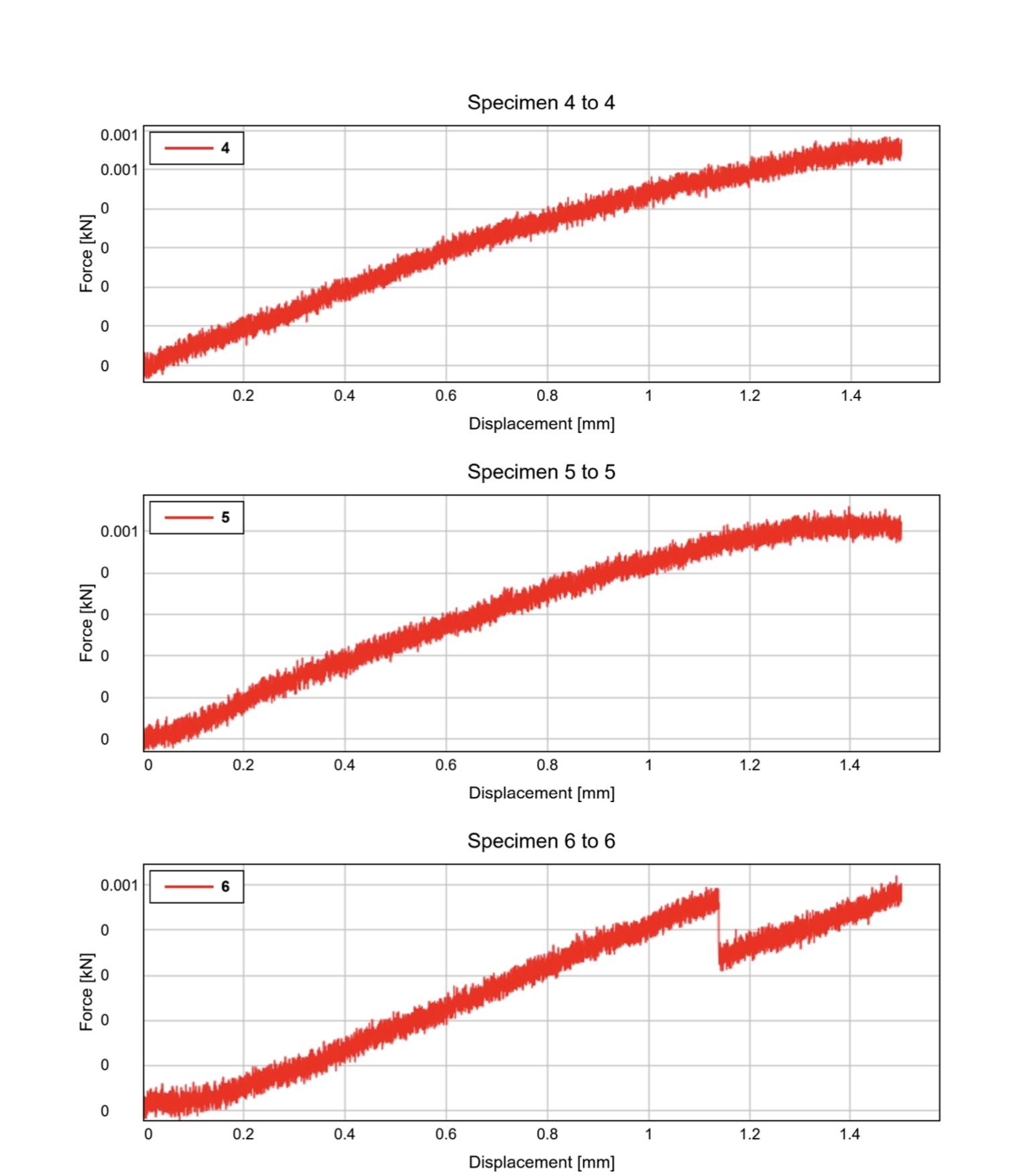
## Testing Procedure

* A three-point bending test was conducted on an Instron universal testing machine.
* Cross-head speed: 1 mm/min.
* Load-deflection values were recorded and analyzed.

# RESULTS



**Figure 1:** Analysis of 3 point bending test for specimens



**Figure 2:** Analysis of 3 point bending test for specimens

The results of reveal that the Autoclave sterilization resulted in a greater reduction in load-deflection values across all wire types, indicating reduced flexibility and increased stiffness. Hot air oven sterilization preserved the flexibility and superelastic properties better than autoclaving. The 0.016 × 0.022 inch wire showed the highest percentage decrease in load after autoclaving.

**Table 1:** Flexural displacement at maximum force

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.No** | **Maximum Force [n]** | **Specimen Label** | **Flexure displacement at maximum force (mm)** | **Flexural strain**  **(displacement)at maximum force (%)** | **Flexural stress at maximum force [Mpa]** |
| 1 | 0.42 | Niti- control | 1.49 | 1.09 | 1094.12 |
| 2 | 0.45 | Niti- control | 1.46 | 1.07 | 1165.80 |
| 3 | 0.56 | Niti- Hot air oven | 1.47 | 1.04 | 1641.34 |
| 4 | 0.58 | Niti- Hot air oven | 1.47 | 1.03 | 1705.93 |
| 5 | 0.56 | Niti- autoclave | 1.40 | 0.98 | 1637.41 |
| 6 | 0.52 | Niti-autoclave | 1.49 | 1.05 | 1524.82 |

# DISCUSSION

NiTi wires are extensively used in orthodontics because of their unique properties such as superelasticity and shape memory effect, which enable efficient tooth movement with minimal patient discomfort [(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/qsEttd/AKM3)[(Sushanthi et al., 2021)](https://paperpile.com/c/qsEttd/dh8rc)[(Harsha et al., 2022)](https://paperpile.com/c/qsEttd/Fu2JC). The integrity of these properties is vital for consistent clinical performance and successful orthodontic outcomes. However, sterilization protocols, while necessary for patient safety, have been shown to alter the mechanical properties of NiTi wires, potentially compromising their performance.

Autoclave sterilization involves high-pressure saturated steam at elevated temperatures, which is effective for eliminating microbial contaminants but may have detrimental effects on the mechanical properties of NiTi wires [(Neha et al., 2021)](https://paperpile.com/c/qsEttd/eOoZO)[(Maliael et al., 2021)](https://paperpile.com/c/qsEttd/S41L7)[(Lakshmi, 2021)](https://paperpile.com/c/qsEttd/k8cna). Studies have shown that repeated autoclave sterilization can cause surface oxidation, increasing friction between the wire and the brackets, thereby reducing the wire's flexibility and superelastic properties [(Dharman 2021)](https://paperpile.com/c/qsEttd/rtjaT).

The reduction in load-deflection values seen in the autoclaved samples in this study aligns with findings from Lemons et al., who reported that autoclave sterilization increased the stiffness of NiTi wires and reduced their elasticity [(Lemons, 1996)](https://paperpile.com/c/qsEttd/ditH). This phenomenon is likely caused by surface oxidation and phase transformation from austenite to martensite, which occurs at elevated temperatures [(Balaji Ganesh S & Sugumar, 2021; Jabin et al., 2021)](https://paperpile.com/c/qsEttd/KD5cg+QWXFY).

Hot air oven sterilization involves exposure to dry heat, which eliminates the risk of moisture-induced oxidation. The results of this study showed that NiTi wires subjected to hot air oven sterilization maintained their flexibility and load-deflection properties better than those subjected to autoclaving. Similar findings were reported by Garg et al.[(Garg & Garg, 2018)](https://paperpile.com/c/qsEttd/ZA0q), who concluded that dry heat sterilization had a lesser impact on the mechanical properties of NiTi wires compared to steam sterilization [(Govindaraj 2021)](https://paperpile.com/c/qsEttd/XEXV+643V+9uwF)

Dry heat sterilization is less aggressive to the NiTi microstructure because it avoids moisture, which is a significant factor contributing to corrosion and phase transformation in NiTi alloys [(Graf et al., 2023; Ramamurthy & Jaiganesh, 2021; Tiwari & Jain, 2023)](https://paperpile.com/c/qsEttd/SnQeV+LhgLT+LHNSa). This may explain why the load-deflection values after hot air oven sterilization were higher than those after autoclaving.

Maintaining the superelastic properties of NiTi wires is crucial for predictable orthodontic outcomes. A decrease in elasticity and flexibility due to sterilization can lead to increased treatment time, patient discomfort, and inefficient tooth movement (22). Hot air oven sterilization appears to be the preferred method for preserving NiTi wire integrity, but autoclaving remains a necessary practice in clinical settings due to its broad microbial elimination capabilities.

# CONCLUSION

This study concludes that autoclave sterilization results in greater degradation of the load-deflection properties of NiTi wires compared to hot air oven sterilization. Hot air oven sterilization preserves the superelastic properties of NiTi wires better, making it a more suitable method for maintaining the mechanical integrity of orthodontic wires. Further studies with larger sample sizes and long-term evaluation are recommended to validate these findings.

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