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Research Article

## Stress Birefringence Generated by Stainless Steel and Titanium-Molybdenum Alloy Using Vertical Loops with Helix

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## Abstract
This study aims to determine and compare the stress birefringence of Stainless steel and Titanium-molybdenum alloy using vertical loops with helix on a photo-elastic model. Fifty six (56) lower premolar teeth were mounted resulting in 28 models. Each model contained lower premolar teeth namely right premolar area and left premolar area. Subsequently, the models were divided right and left lower premolar teeth and grouped into A and B, respectively. Group A Stainless steel (SS) wire, and Group B Titanium-molybdenum alloy (TMA) wire. Images were taken after engaging the wire, after 1 hour of application of force, stress birefringence were observed, and uploaded into a software called Fiji (Image J). The green histogram analysis of a sample was calculated by taking the average of 2 lower premolar teeth area. The green hue was considered for the histogram analyis of each image. This was according to American Society of Testing Materials, in which black was the lowest fringe order and green was the highest.The mean value of each image was tabulated and subjected to independent Samples Test using SPSS software version 20. There was no significant difference between means and standard deviations of the stress birefringence generated by Stainless steel and Titanium-molybdenum alloy using vertical loops with helix.The results stated having same stress birefringence generated by Stainless steel and Titanium-molybdenum alloy using vertical loops with helix.

## Keywords
Space Closure, Stainless Steel wire, Titanium-Molybdenum Alloy, Vertical loops with helix, Fiji (Image J).

## Declaration of Conflicting Interest
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Introduction
Stainless Steel (SS) wires have been used in orthodontic treatment since 1950, due to their formability, low cost, and its acceptable clinical performances. Titanium-molybdenum alloy (TMA) wires were developed around 1980 by Charles J. Burrstone, which was introduced by Ormco Company (Ormco, WestCollins, USA). It has been used to apply less force compared with SS.

The Stainless steel alloys, in comparison to the noble metals, are relatively cheaper. The Stainless steel alloys contains Chromium (17-25%), Nickel (8-25%) and Carbon (1-2%). Stainless steel arch-wires have high stiffness, low springiness, low friction, and good formability.

Titanium-molybdenum alloy (TMA) is a stabilized titanium alloy in the beta phase composed of titanium (79%), molybdenum (11%), zirconium (6%), and tin (4%). This alloy presents spring back greater than the steel, and a combination of adequate shape memory, medium stiffness, high friction and good formability. Alloy offers a good combination between stiffness and elasticity, which provides good characteristics for finishing stage in orthodontic treatment.

Over the years, different loop configurations for closing spaces are used to provide a dental movement. Therefore, during the selection of the best-indicated model for each case, some variables such as loop design, thickness, and properties of the wire used, type of movement desired and amount of force necessary, must be taken into consideration.

The incorporation of helix is an important factor to take into consideration. This is associated with the longer wire in the inter-bracket space, which promotes increase in activation; amplitude of the loop and reduction of the amount of horizontal force produced.

Photo-elastic analysis is a widely used optical technique for examining and measuring stress distribution in structures exposed to internal or external forces. In dentistry, photo-elasticity was introduced by Zak in 1935 during the study in which he assessed the type of tooth movement, strength, and point of application of the forces. In orthodontics, this technique has been used to examine the stresses.

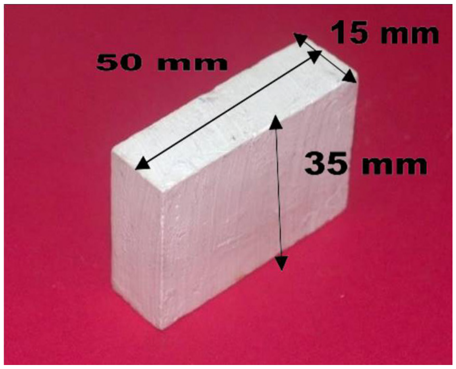


**Figure 1** A white stone block

**Figure 2** The future mould space for the resin.

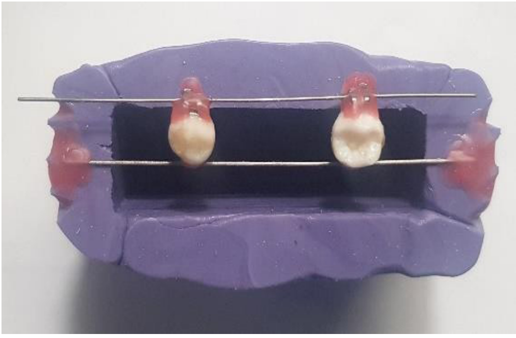

**Figure 3** The moulds made out of the condensation silicone and stabilized wires.

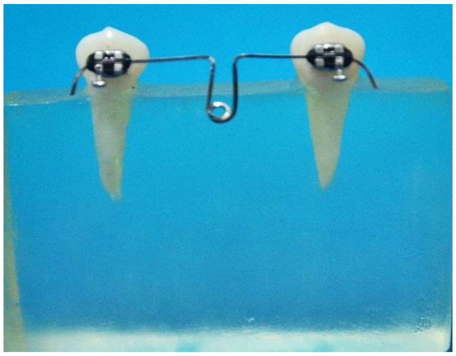

**Figure 4** A sample of group A (SS wire)

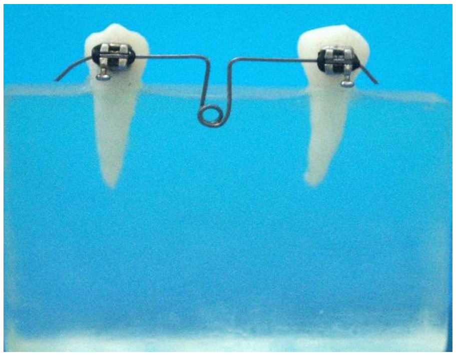

**Figure 5** A sample of group B (TMA wire)

In this study, we focused on objective evaluation through stress birefringence in a photo-elastic model of the force systems generated by the centralized vertical loop with helix made of SS and TMA wires, both 0.017 x0.025.

## Materials and Methods

In the study, 28 sets (fifty-six brackets) of 022 slot Bionic standard, edgewise brackets were placed on the lower premolar teeth. The brackets were placed according to standard bracket heights using light cured Resilience cement before placing the teeth in the photo-elastic resin. Excess resin around the brackets was removed.

The photo-elastic model was prepared using epoxy resin and hardener according to manufacturer's instructions and sound natural teeth free of extensive caries, enamel defects were embedded in the resin.

A white stone block of dimensions fifty millimeter by fifteen millimeter by thirty-five millimeter was used for creating the mould space for the epoxy resin. The white stone block was based on the measurements from a previous pilot study block made out of illustration board (Guilherme, 2011).

Condensation silicone material, a putty and catalyst were used to make impressions of the white stone block, which was creating the future mould space for the resin. Separating medium such as Vaseline was applied on the white block stone so that it can be removed from the silicone mould easily. The condensation silicone impression was created the mould space for the resin to be poured.

The photo-elastic model was prepared by positioning the two teeth separated by at inter-bracket distance of 27mmusing an orthodontic caliper.

Epoxy resin and hardener were taken in two separate plastic graduated containers (4:1 ratio). The hardener was poured in the plastic container containing the epoxy resin and mixed using an ice cream/popsicle stick according to manufacturer's instruction for about five to ten minutes. Air bubbles were avoided during mixing. The resin was allowing resting for few minutes to remove any remaining air bubbles.

The teeth segments were placed in the mould made out of the condensation silicone and stabilized wire using 0.18 a round SS wire inside brackets slots with sticky wax over the brackets to keep the brackets free from any extra resin and 0.36 round wire on the lingual surface of the teeth with sticky wax over the ends of stabilizing wire

Now a syringe was used to pour the resin into the mould spaces with the teeth segments. The resin was filled up to two mm below the cervical region of the teeth.

The resin with the embedded teeth was allowed to cure completely at room temperature for a period of about twenty-four hours. After about twenty-four hours, the models were removed from the silicone moulds and the stabilizing wires were removed. The models were placed in the Polari-scope set up to check if there is any stress in the models before application of forces.

Fourteen such models were prepared for the Stainless steel and fourteen for Titanium-molybdenum alloy (with vertical loop with helix)

The set up was consisted of the light source with the polarizing filter fifty eight mm (HOYA brand), the prepared photo-elastic model, a Nikon D5100 camera with fifty two millimeter lens were fitted with a fifty two millimeter polarizing filter respectively.

Two (2) groups of vertical loops with helix were built:

- For the first group, 14 springs were made of 0.017 X0.025 SS wire including helix .

- For the second group, 14 springs were made of 0.017 x 0.025 TMA wire including helix .

The springs were placed in the horizontal Slot of the brackets, centralized at a 27-mm distance. Photographs were taken after loading of force on each sample to assess the stress birefringence. The vertical loops were activated 2 mm and force was applied for 1 hour on each model.

The tests were performed using a circular Polari-scope, which was comprised of light system, two polarizers, support to handle the photo-elastic model, and a digital camera to record the results.

After activating the vertical loop, the fringe order in the radicular surface was seen in the sample. Observations were recorded and compared for each group.

Each model was divided into two areas, namely: Right Premolar Area (RPA), and Left Premolar Area (LPA)

Each area was subjected to Fiji (Image J) software, in which the histogram of each region is evaluated. The value of the green histogram analysis was the preferred color in reference to American Society for Testing

| Area | The value of the green histogram analysis |
|---|---|
| RPA | 141.966 |
| LPA | 111.380 |
| Sample A 1 | 126.673 |

**Table I:** AThe value of the green histogram analysis in model A1

| Area | The value of the green histogram analysis |
|---|---|
| RPA | 109.039 |
| LPA | 99.530 |
| Sample B 1 | 104.2845 |

**Table II:** The value of the green histogram analysis in model B1

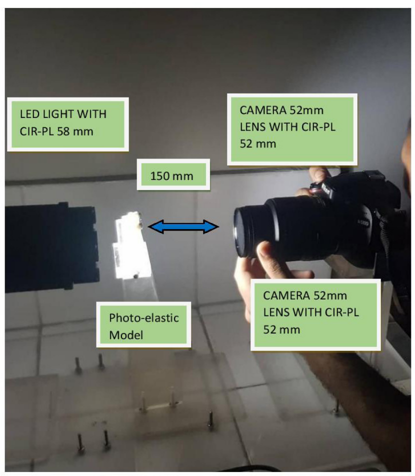


**Figure 6** Polari-scope set up

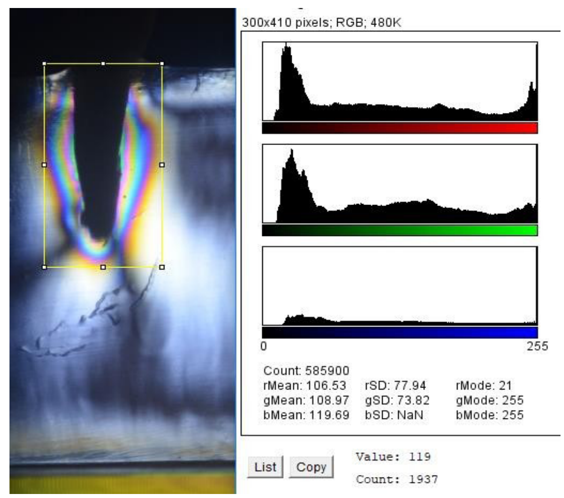


**Figure 7** Histogram Analysis of Right Premolar Area RPA

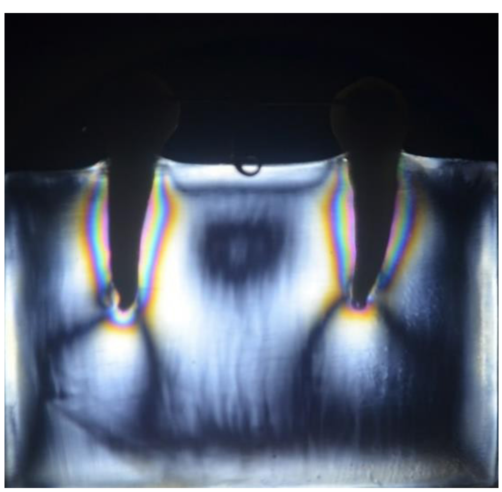

**Figure 8** Model A1

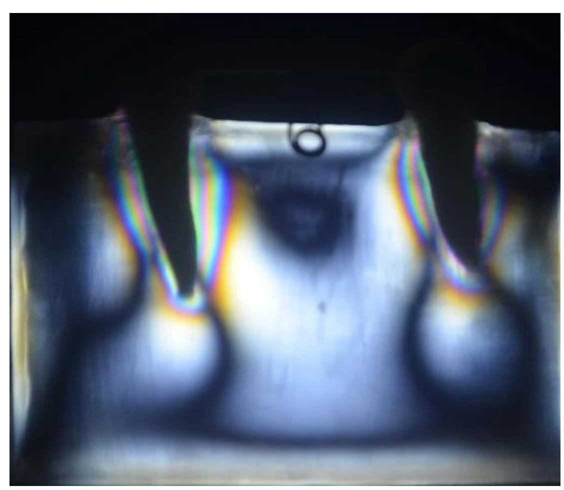

**Figure 9** Model B1

and Materials in which green valued highest for stress. The data gathered were tabulated per group and compared with one another.

## Statistical Analyzing Data

This study is a quantitative type of study where the stress birefringence was produced by the usage of vertical loops with helix made of stainless steel or titanium-molybdenum. It was analyzed and recorded with the aid of graphs.

The green histogram analysis of a sample was calculated by taking the average of 2 lower premolar teeth area.

The results were grouped accordingly. The two groups were compared based on the resultant images of stress birefringence distribution. The type of the test methods to be used in this study was independent T Test.

In model A1, the value of the green histogram analysis in right premolar area is 141.966, and in left premolar area is 111.380. It was read by using Fiji (image J) software.

The value of the green histogram analysis in the whole sample is 126.673. It was read by calculating the average of right premolar area and left premolar area.

In model B1, The value of the green histogram analysis in right premolar area is 109.039, and in left premolar area is 99.530.It was read by using Fiji (image J) software.

The value of the green histogram analysis in the whole sample is104.2845. It was read by calculating the average of right premolar area and left premolar area.

## T-Test

The mean value of the green histogram analysis in SS group is 136.4667, while the mean value of the green histogram analysis in TMA group is 130.2413.

Shapiro-wilk test shows no significant difference in SS and TMA groups.
Therefore, the data is normally distributed and parametric test can be applied.
Independent t test shows no significant difference between stress of SS and TMA (P=.106).

| Descriptive Statistics | | | | | |
|---|---|---|---|---|---|
| | Material | N | Mean | Std. Deviation | Std. Error Mean |
| Post | SS | 14 | 136.4667 | 7.75840 | 2.07352 |
| | TMA | 14 | 130.2413 | 11.54778 | 3.08627 |

**Table III:** Descriptive statistic

| | Total | Group A | Group B |
|---|---|---|---|
| Shapiro-Wilk test for normality<br>Interpretation | 0.091<br>Normally distributed | 0.274<br>Normally distributed | 0.372<br>Normally distributed |

**Table IV:** Shapiro-Wilk test

| | | t-test for Equality of Means | | |
|---|---|---|---|---|
| | | t | df | P - Value |
| Post | Equal variances assumed | 1.674 | 26 | .106 |

**Table V:** Independent samples T test

## Results

The stress birefringence was measured by the green value of the histogram analysis using the independent t-test to compare the means and the standard deviation between the stress birefringence generated by vertical loops with helix made of Stainless steel and Titanium-molybdenum alloy with confidence interval of 95%.Null Hypothesis is rejected if $t \geq 2.056$, or $p < 0.05$

Reject null hypothesis if $t \geq 2.056$, or $p < 0.05$ ($t=1.674$, $p=.106$)

So, null hypothesis is accepted. There is no significant difference between means and standard deviations of the stress birefringence generated by vertical loops with helix made of Stainless steel (M=136.4667, SD=7.75840) and Titanium-molybdenum alloy (M=130.2413, SD=11.54778). $t(26) = 1.674$, $p=.106$

## Discussion

Badran, Orr, Stevenson, and Donald J. Burden (2003) made a study about photo-elastic stress analysis of initial alignment arch-wires .They found that, multi-strand Stainless steel arch-wires and super-elastic nickel titanium arch-wires transfer similar stresses to the roots of the teeth.

Kapila and Sachdeva (1989) made a study about mechanical properties and clinical applications of orthodontic wires. They found that, Stainless steel wires have remained popular since their introduction to orthodontics because of their formability, biocompatibility, and environmental stability, low cost, but high stiffness, which in turn produce high force. In addition, these proponents found that Beta-titanium wires provide a combination of adequate spring-back, average stiffness, and good formability.

Carlos (2011) made a study about friction force on brackets generated by stainless steel wire and super-elastic wires. He found that a great disadvantage of wires made of Beta-titanium or Titanium-molybdenum alloy, known as TMA, is producing high friction force, up to eight times higher than that of stainless steel wires.

In this study, the force that produced from stiffness of Stainless steel alloy and friction of Titanium-molybdenum alloy appear as a stress birefringence in a photo-elastic model.

Therefore, according to the present result, there is no significant difference between means and standard deviations of the stress birefringence generated by Stainless steel and Titanium-molybdenum alloy using vertical loops with helix.

## Conclusion

From the results of this study, the following could be concluded:

The results stated having no significant difference between means and standard deviations of the stress birefringence generated by vertical loops with helix made of Stainless steel and Titanium-molybdenum alloy. Therefore, same stress birefringence generated by both materials.

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