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Effect of clinical use and sterilisation on Mechanical properties of Ni-Ti orthodontic wires.

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Introduction

Ni-Ti wires have been introduced into orthodontic practice since 1970[1] , this has greatly simplified the alignment and levelling steps due to its modulus of elasticity which is four to five times lower than that of steel[1,2,3,4]. But also to its shape memory properties for the latest generations of Japanese Ni-Ti archwires or Copper Ni-Ti.

Since their appearance in the field of orthodontics, Ni-Ti wires have considerably evolved in the direction of improving their mechanical properties.

Their main advantage is the high elasticity. However, as soon as the force applied to the wire exceeds a certain value, the deformation becomes permanent[2,4].

The second great advantage of Ni-Ti wires is the super-elasticity. This property, obtained by improving heat treatment conditions, allows practitioners to correct more severe dental malpositions, while having better control with thicker sections.

Shape memory is the third advantage of these archwires, obtained by a thermo-mechanical treatment which imposes a particular arch shape[5,6,7].

Undoubtedly, these archwires have a number of drawbacks including their high price, which is five to forty times more expensive than other archwires on the market, thus increasing the cost of orthodontic treatment considerably. A number of practitioners tend to sterilize and recycle them for secondary or even tertiary use [6,9,10].

In a 1986 study by Buckthal[11], based on a survey sent to American orthodontists, 52% of practitioners who use nickel-titanium archwires recycle them after disinfecting them. The most common reason given for reusing these archwires was the high cost. Approximately 55% of clinicians who recycled these archwires indicated that deterioration of the wire properties was their main concern.

This recycling, which is economically advantageous for practitioners, is only possible, however, on the sole condition that clinical use followed by sterilization does not affect the properties of the archwires.

For this, it is necessary to evaluate the effect of sterilization on their mechanical properties, which can have a direct impact on their use.

In order to evaluate these properties, the tensile test is certainly the most widely used test to evaluate the elasticity of the wire, the ultimate tensile strength and the percentage of elongation at break. Its execution is easy thanks to a modern tensile testing machine which has an adjustable electric drive to carry out simple or cyclic tests at controlled speed[12].

In the orthodontic literature there are many studies that have been interested in studying the effect of sterilization on the mechanical properties of orthodontic archwires, mainly Ni-Ti archwires, but the majority are in-vitro studies performed in the laboratory and thus do not come close to clinical reality.

It is in this sense that we envisaged this clinical and experimental study whose objective was :

- to study the effect of sterilization alone on the mechanical properties of orthodontic Ni-Ti archwires.
- to study the effect of intraoral use and sterilization on the mechanical properties of orthodontic Ni-Ti archwires.

Materials and methods

In this study, 30 preformed Ni-Ti (ORMCO®) orthodontic archwires measuring 017x.025 inches and 15 cm in length were used.

These archwires have been divided into 3 groups of 10 archwires :

Group 1: 10 new archwires "control group".

Group 2: 10 new archwires cold sterilized in a freshly prepared 2% glutaraldehyde solution for 10 hours according to the manufacturer's recommendations. The wires were then rinsed under running water, dried, packed and sterilized in a autoclave.

The autoclave cycle was maintained at 121°C for 30 minutes "1st experimental group".

Group 3: 10 new archwires sterilized in the autoclave after a cycle of intraoral use.

The clinical use cycle was defined as a period of 4 weeks.

After intraoral use, all wires were disinfected for 10 minutes to remove all debris, wiped, dried with absorbent paper and packed before being placed in the autoclave.

The autoclave cycle was maintained at 121°C for 30 minutes. "2nd experimental group".

For the mechanical tensile test, all the archwires were tested by a Universal testing machine , Lloyd LR50K Plus series at the Technical Center for Plastics and Rubber (TCPC) within the Centre for Studies and Research of the Metallurgical, Mechanical, Electrical and Electronic Industries of Casablanca (CSRMMEEI).

Each wire was fixed in the machine jaws with a distance of 50mm between the jaws and under the following test conditions:

- Temperature: 23 ± 2 °C
- Humidity: 50 ± 10%.

The machine was operated in the (ISO 527 mode 1996 - traction) with a speed of 1 mm per minute. This was kept constant for all thirty wires tested.

Two characteristics of each sample were quantified from the readings: ultimate tensile strength (Mpa) and elongation rate (%).

The data were recorded from a computer connected to the machine.

The results for tensile strength and percent elongation were determined for the 30 archwires in the study and compiled in Excel tables.

The averages of the values were calculated for each group of archwires.

Statistical comparisons between the three groups were performed using the student's T-test with the EPI-info software version 7.0.

Results

Table 1: Mechanical properties of Group 1 Ni-Ti arcs (new Ni-Ti)

N°	Tensile strength (MPa)	Elongation at break test
1	1100	14.5
2	1210	14.9
3	1313	16.9
4	1148	14.0
5	1278	14.0
6	1268	14.7
7	1339	14.9
8	1337	17.2
9	1117	13.6
10	1142	13.5

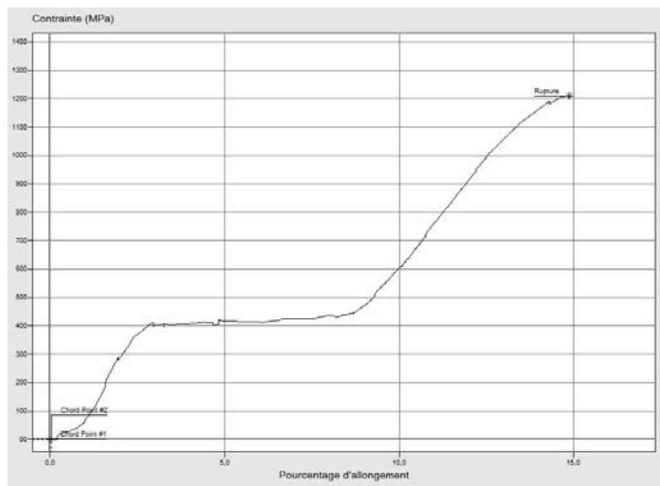
Table 2: Mechanical properties of Group 2 Ni-Ti arcs (new sterilized Ni-Ti).

N°	Tensile strength (MPa)	Elongation at break test
1	1011	12.2
2	1222	14.2
3	1025	10.2
4	1251	11.9
5	1113	12.1
6	1217	11.0
7	1285	11.8
8	1497	13.8
9	1289	13.6
10	1307	14.2

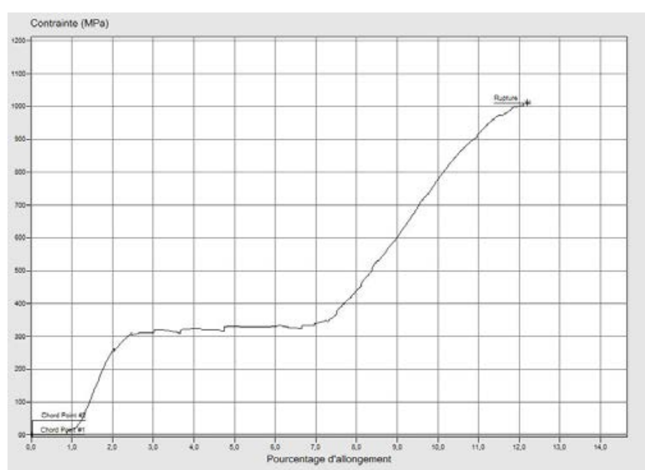
Table 3: Mechanical properties of Group 3 Ni-Ti arcs (Ni-Ti used and sterilized).

N°	Tensile strength (MPa)	Elongation at break test
1	1192	10.0
2	1274	17.6
3	965	16.7
4	1124	16.2
5	1044	14.0
6	989	14.0
7	1142	13.0
8	1025	14.0
9	1110	13.2
10	1205	14.0

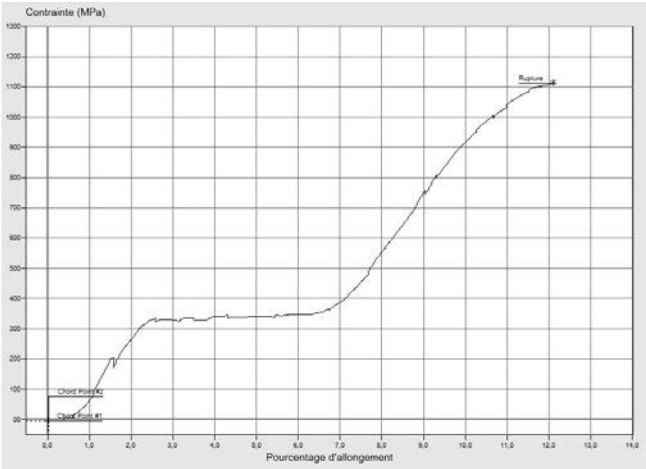
Load / deflection curve of a new Ni-Ti arc



Load / deflection curve of a Group 2 Ni-Ti arc



Load / deflection curve of a Group 3 Ni-Ti arc



Thus, the following table shows the differences in the means and standard deviations of the tensile strength and the elongation at break test of the 3 groups studied

Table 4 : The means and standard deviations of the tensile strength and of the elongation at break test of the 3 groups studied.

Groups	Control group (GI)		1st experimental group (GII)		2nd experimental group (GIII)	
	Mean	SD	Mean	SD	Mean	SD
Tensile strength (MPa)	1231	38,9	1107	20,3	1221,7	12,9
Elongation at break test	15	1,76	14	1,02	12,5	0,48

The statistical comparison between the control group and the first experimental group (10 archwires cold sterilized in a freshly prepared 2% glutaraldehyde solution for 10 hours according to the manufacturer's recommendations. The wires were then rinsed under running water, dried, packed and sterilized in an autoclave. The autoclave cycle was maintained at 121°C for 30 minutes) showed no significant difference in tensile strength and elongation at break.

Table 5: Statistical comparison between the control group and the first experimental group.

Groups	Control group (GI)		1st experimental group (GII)		P value	sig
	Mean	SD	Mean	SD		
Tensile strength (MPa)	1231	38,9	1107	20,3	.346	NS
Elongation at break test	15	1,76	14	1,02	.624	NS

On the other hand, the statistical comparison between the control group and the 2nd experimental group (10 new archwires sterilized in an autoclave after a 4-week cycle of intraoral use. Then, all wires were disinfected for 10 minutes, wiped, dried and packed before being placed in the autoclave. The autoclave cycle was maintained at 121° C for 30 minutes) showed a significant difference in the elongation at break variable.

Table 6 : Statistical comparison between the control group and the second experimental group.

Groups	Control group (GI)		2nd experimental group (GII)		P value	sig
	Mean	SD	Mean	SD		
Tensile strength (MPa)	1231	38,9	1221,7	12,9	.0543	NS
Elongation at break test	15	1,76	12,5	0,48	4,342	S

Indeed, the elongation at break decreases significantly compared to the control group after clinical use and sterilization of Ni-Ti archwires, this shows a degradation of the mechanical properties after clinical use of the archwires.

Discussion

The purpose of the study we conducted was to evaluate the effect of sterilization alone, as well as the effect of intraoral use and sterilization on the mechanical properties of orthodontic Ni-Ti archwires.

Our work is based on an in vivo experimental study in which we studied the mechanical properties of 10 Ni-Ti (ORMCO®) archwires placed in the mouth for 4 weeks followed by an autoclave sterilization cycle. This is an advantage for us since most of the studies that have dealt with this subject are in vitro experimental studies[13,14,15,10,16.]

30 orthodontic Ni-Ti (ORMCO®) archwires, subdivided into 3 groups of 10 archwires, were used, in accordance with the data in the literature, the majority of which consist of about 10 archwires per group [17,9,20,8,18].

In this case, we chose the tensile test in order to study the mechanical properties of Ni-Ti archwires, because it is the most frequently used test to determine the mechanical behaviour of a material, and also because it is characterised by its ease of use and the wealth of information it provides[21]. The archwires were analysed using an Universal testing machine , Lloyd LR50K Plus series at the Technical Center for Plastics and Rubber (TCPR), within the Centre for Studies and Research of the Metallurgical, Mechanical, Electrical and Electronic Industries in Casablanca (CSRMMEEI). It is true that the machine at our disposal is designed for large samples, but the jaws have been modified in order to be able to carry out the test directly on the orthodontic archwire.

We can conclude that the main result of our work is that there is a degradation of the mechanical properties of the archwires used in the mouth and sterilized in the autoclave.

Indeed, there is a statistically significant decrease in the elongation at break variable after a cycle of intraoral use and autoclave sterilization compared to the control group consisting of new archwires.

While cold sterilization (2% glutaraldehyde) followed by sterilization in an autoclave appeared to have no effect on mechanical properties, there was no statistically significant difference in tensile strength and percent elongation at break compared to the control group.

Our results were consistent with those of Sunil Kapila[22] who conducted a study to determine the effects of 8 weeks of in vivo recycling followed by a dry heat sterilization cycle on the mechanical characteristics of two types of Ni-Ti alloy wires.

They concluded that clinical use introduced increased wire loading and unloading forces. These results indicate that clinical reuse reduces the pseudoplasticity and pseudoelasticity of Ni-Ti wires. This is consistent with our results. Devaprasad AP and colleagues[10] also showed a significant 5% decrease in tensile strength between the unused wire and the wire used in the mouth for 6 months. However, the effects of autoclaving were not observed in their study.

More recently, Michal Sarul and al[24] concluded that the oral cavity environment has significantly changed the mechanical properties of Ni-Ti wires,

We also cite the work of Smith who studied the effect of various sterilization protocols (autoclave, cold sterilization, dry heat sterilization and pre-desinfection) on several types of archwires, including three Ni-Ti alloys, whose conclusion showed that sterilization does not alter the properties of NiTi.

Furthermore, with regard to the effect of sterilization alone on the mechanical properties of Ni-Ti archwires, there are numerous studies that are in line with the fact that sterilization does not affect the mechanical properties of NiTi archwires, such as the work of Pernier's team[25] , that of Brindha[26] and again that of Sridhar Kannan[15].

Recycling involves repeated exposure of the wire for several weeks to mechanical stress and oral environmental elements as well as sterilization. The combined effects of use and sterilisation may subject the wire to alterations in its properties[12].

And so we can conclude that there is a degradation of the mechanical properties of archwires used in the mouth and sterilized rather than when they are only sterilized.

Conclusion

Our study has once again confirmed the effect of clinical use and sterilization on orthodontic Ni-Ti archwires. We are convinced that financial reason does not outweigh the clinical benefit derived from these archwires. Their super elasticity is their success. If this property deteriorates, the expected result may be unpredictable.

The orthodontist must have a spirit of medical ethics, because we are doctors first and "primum non nocere" should be our motto. Also, we are now sure that the archwires are subject to surface degradation and mechanical behaviour. We then advised orthodontic practitioners to :

- Use very good quality Ni-Ti archwires.
- Do not reuse archwires as much as possible.
- And in case of reuse, tolerate only one and not several reuses.

It must be said that with the increasing number of orthodontic suppliers and firms producing orthodontic equipment, prices have dropped significantly in recent years. Therefore, financial gain should no longer be the only reason to reuse orthodontic archwires.

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