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Are more nickel ions released from NiTi wires after sterilisation?

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Background: Increased concentrations of nickel ions may be released into saliva from recycled NiTi archwires.
Aim: To compare the nickel ion concentrations released from recycled NiTi wires after sterilisation by either dry heat or steam autoclave.
Methods: Eighty preformed NiTi wires were assigned to four equal groups. In Groups 1, 2 and 3 the archwires were used intra-orally for 4 weeks. The Group 4 archwires were not used. Group 1 archwires were sterilised by dry heat, the Group 2 archwires were sterilised by steam autoclave, the Group 3 archwires were not sterilised and the Group 4 archwires were as-received. A 2 cm length, cut from each archwire, was immersed in artificial saliva for 4 weeks and the nickel ion concentrations in the artificial saliva measured with an atomic absorption spectrophotometer.
Results: There were no significant differences in the nickel ion concentrations released into the artificial saliva by each group of archwires ($p = 0.467$).
Conclusion: Sterilisation of used NiTi wires by either dry heat and steam autoclave does not affect the concentrations of nickel ions released into artificial saliva.
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Introduction

Archwires made from NiTi alloys are frequently used during orthodontic treatment. Although these archwires contain more than 50 per cent nickel, a known cytotoxic agent, no biological effects caused by these archwires have been reported.[1–6] Hypothetically, nickel ions released from NiTi archwires, particularly during prolonged use and/or after sterilisation, could lead to unacceptable levels of this ion in the saliva and nickel hypersensitivity.[7] Nickel is the most common cause of metal-induced allergic contact dermatitis.[8,9] Ten years ago, between 10 and 20 per cent of the female population in Europe were reported to be allergic to nickel.[10]

Reuse of NiTi archwires has been advocated because of the high cost of these materials compared with stainless steel archwires.[11] There is a lack of information about the release of nickel ions following prolonged clinical use and following sterilisation. Since the 1980s several studies have investigated changes in the mechanical properties of orthodontic wires following sterilisation,[12–15] but there has been surprisingly little interest in the metal ions released from orthodontic appliances. Nickel and cobalt released from orthodontic appliances can induce DNA damage in oral mucosa cells.[16] Factors such as a low pH, fluoride additives and the duration of immersion could promote release nickel ions from NiTi wires.[17–19] Obviously, high corrosion resistance is a necessary requirement for biocompatibility of these wires during use and following sterilisation by dry heat or steam autoclave. The aim of this investigation is to compare the nickel ion concentrations released from used NiTi wires after sterilisation by either dry heat or steam autoclave.

Table I. Nickel ions released from NiTi archwires as-received from the supplier (1), used and not sterilised (2), used and sterilised by dry heat (3), used and sterilised with a steam autoclave (4).

Group	Number	Mean±SD (μg/L/28 days)	Minimum	Maximum
1	20	4.7 ± 2.26	1.2	9.1
2	20	4.7 ± 2.21	1.6	8.2
3	20	3.8 ± 2.07	1.7	8.3
4	20	4.6 ± 2.13	0.6	8.1

ANOVA, $p = 0.467$

Table II. Post hoc comparisons of the nickel ions released by NiTi archwires into artificial saliva, probability values only.

Group	2	3	4
1	0.627	0.996	0.995
2		0.491	0.473
3			1.000

Group 1 – as-received from the supplier;
Group 2 – used and not sterilised;
Group 3 – used and sterilised by dry heat;
Group 4 – used and sterilised with a steam autoclave

Materials and methods

Eighty 0.014 inch round preformed NiTi wires (Rematitan Lite, Dentaurum, Germany) were assigned to four equal groups. The archwires in Group 1 were kept 'as-received' from the supplier, and those in Groups 2, 3 and 4 were ligated with elastomeric modules in 0.018 inch stainless steel brackets bonded to the teeth in 60 patients. The patients were requested not to use mouthrinses during the experiment. After 28 days use the archwires were removed and wiped clean with cotton gauze pads soaked in 70 per cent isopropyl alcohol.

The archwires in Group 2 were not sterilised. The Group 3 archwires were sterilised by dry heat at 170°C for 60 minutes, and the Group 4 archwires sterilised in a steam autoclave, operated at 2.5 kg/cm2 pressure and 135°C for 4–5 minutes. Modified Fusamaya artificial saliva, which had the following composition: NaCl (0.4 gr/l), KCl (0.4 gr/l), $CaCl_2.H_2O$ (0.8 gr/l), $Na_2S.5H_2O$ (0.01 gr/l), $CO(NH_2)_2$ (Urea) (1 gr/l) and distilled water (1000 ml), adjusted to pH 6.5 and maintained at 37°C throughout the experiment, was used. A 2 cm straight length of wire, cut from the distal section of each archwire, was suspended in 1.4 ml of the artificial saliva in glass containers and placed in an incubator at 37°C for 28 days. The electrolyte (artificial saliva) was examined for nickel content with an atomic absorption spectrophotometer.

A graphite furnace atomic absorption spectrophotometer (AA-670, Shimadzu, Japan) was used to detect nickel ions (μg/L) released from the specimens into the electrolyte. The Kulmogrov-Smirnov test was used to determine if the data were normally distributed. The concentrations of nickel ions in each group were compared with ANOVA and post-hoc tests as required.

Results

The mean concentrations of nickel ions released into the electrolyte by the archwires as-received from the supplier (Group 1), used for 28 days but not sterilised (Group 2), used for 28 days and sterilised by dry heat (Group 3) and used for 28 days and sterilised in a steam autoclave (Group 4) are given in Table I. There were no statistically significant differences between the groups: the probability values ranged from 0.627 to 1.000 (Table II).

The highest mean concentration of nickel ions and the most variable was from the archwires in Group 1. The lowest mean concentration and one of the least variable was from the archwires sterilised by dry heat. The concentration of nickel ions released into the electrolyte after dry heat sterilisation was approximately 20 per cent lower than the nickel concentrations released by the wire samples in the other groups. The mean concentrations of nickel ions released into the electrolyte over 28 days ranged from 3.8 μg/L (Group 3) to 4.7 μg/L/28 days (Groups 1 and 2).

Discussion

Our results indicate that sterilisation of used NiTi archwires by dry heat or steam autoclave does not increase the release of nickel ions into artificial saliva. The concentrations of nickel released into the electrolyte were considerably lower than the nickel levels reported in other in vitro studies.[18,19] A slightly lower mean concentration of nickel ions was found in the electrolyte after dry heat sterilisation, but the difference was not statistically significant. The highest mean concentration of nickel ions, released from the 2 cm lengths of archwire we used, was 4.7μg/L in Group 1 (as-received) and Group 2 (used but not sterilised). In a full mouth appliance with two NiTi archwires, the total length of archwire exposed to the saliva is approximately 28 cm. We estimate that the total concentration of nickel ions released from two full archwires over 28 days is approximately 65.8 μg/L. This concentration is well below the critical concentration 600–2500 mg μg/L or higher over a 24 hour period necessary to induce allergy, and it is less than the daily dietary intake level (300–500 μg).[20,21]

Nickel released from orthodontic appliances may be increased by certain foods and drinks, mouthwashes, high temperatures, electrochemical corrosion and fretting during mastication and swallowing, and when added to the level present in the diet may result in an allergy. Cioffi and coworkers[18] investigated the combined effects of strain and fluoridated media on NiTi archwires, and concluded that the corrosion behaviour of NiTi alloy was affected by the fluoride content of the electrolyte. They reported that nickel ions could be released at a rate of 4.79 ± 0.10 μg/cm^2/day in phosphate buffered saline with 0.1% NaF. The short lengths of NiTi wire we used were not loaded or suspended in a fluoride solution, which may account for the lower concentrations of nickel ions we found. This conclusion is supported by Jia et al.[1] who subjected NiTi wires to soaking and cyclic straining and reported significantly higher concentrations of nickel ions were released compared with wires that were passively soaked in a synthetic saliva solution.

Fretting during normal use, acidic foods and drinks, fluoride mouthwashes and electrochemical reactions with other metals, are some of the conditions likely to cause loss of the protective oxide barrier and release of nickel ions into the mouth.[17,19,22–24] Autoclaving used NiTi archwires does not appear to alter either the load-deflection properties of the wires, the surface features or their resistance to corrosion,[13,25] and dry heat sterilisation may have slightly improved the corrosion resistance of the NiTi wire samples by replacement of the native oxide barrier with a new more uniform barrier.[26]

Our findings suggest that the concentrations of nickel ions released from used and sterilised NiTi archwires are very low and when added to the nickel ions from normal dietary sources, the concentration of nickel ions should not exceed the critical level for an allergy to develop.[20] Our study was undertaken in static conditions, whereas orthodontic appliances are normally subjected to a wide variety of physical and chemical conditions, which may also vary widely from individual to individual. Should nickel sensitivity develop, clinicians should be aware that the nickel components of an orthodontic appliance(s) may have contributed to the problem.

Conclusions

Sterilisation of used NiTi wires by either dry heat or steam autoclaving does not affect the release of nickel ions from NiTi archwires into artificial saliva. The concentration of nickel ions released from used and sterilised NiTi archwires into artificial saliva was below the critical concentration required to induce nickel hypersensitivity.

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