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Heating of metallic orthodontic devices during anti-aging treatment with vacuum and electromagnetic fields: In vitro study

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Abstract

Background: The physical appearance of an individual plays a primary role as it influences the opinion of the viewer. For this reason, orthodontic therapy to improve perceived aesthetics is in high demand among patients. This factor, combined with the increase in the number of non-invasive facial aesthetic treatments, has led to the need to understand potential risk factors in the application of medical devices to the perioral skin in patients with fixed orthodontic appliances. The aim of this study was to evaluate in vitro heating of the orthodontic bracket following electromagnetic fields and negative pressure (V-EMF) used as an anti-aging treatment.

Methods: Two different types of titanium alloy wires, one made of "beta-Titanium" alloy and the other "Ni-Ti" (DW Lingual Systems GmbH—Bad Essen—Germany) were used. The orthodontic wires and brackets mounted on a resin mouth were covered with porcine muscle tissue, then subjected to anti-aging therapy with a Bi-one Life-TouchTherapy medical device (Expo Italia Srl—Florence—Italy) which generates a combination of vacuum and electromagnetic fields (V-EMF) already adopted for anti-aging therapy. During administration of the therapy, the orthodontic brackets and porcine tissue were thermally monitored using a Wavetek Materman TMD90 thermal probe (Willtek Communications GmbH—Germany). In total 20 orthodontic mouths were used, 10 with Beta Titanium wires and 10 with Nickel Titanium wires.

Results: A temperature increase of about 1°C was recorded in each group.

The outcome of the present research shows that the absolute temperatures measured on orthodontic appliances, which, despite having a slightly different curve, both show an increase in temperature of 1.1°C at the end of the session, thus falling well within the safety range of 2°C as specified by the standard CENELEC EN 45502-1. Therefore, V-EMF therapy can be considered safe for the entire dental system and for metal prostheses, which tend to heat up at most as much as biological tissue (+0.9°C/1.1°C vs. 1.1°C/1.1°C).

Conclusion: In conclusion, anti-aging therapy with V-EMF causes a thermal increase on orthodontic brackets that is not harmful to pulp health.

KEYWORDS
anti-aging treatment, electromagnetic fields, heating bracket, orthodontic devices, vacuum

1 | INTRODUCTION

The appearance of an individual plays a primary role as it influences the opinion of the viewer. Unconscious considerations that the brain performs have deep and ancestral roots. In this context, it is a common belief that people with a pleasant appearance are more likely to obtain higher paying and prestigious jobs, as well as have happier marriages.[1] In social interaction, attention is usually directed towards the mouth and eyes on the face of the person speaking, suggesting that a smile is an important feature of facial appearance.[2,3] Therefore, a healthy and aligned smile gives a person's appearance pleasantness. As a result, malocclusion has a negative impact on self-esteem and physical, social, and psychological wellbeing.[4] Therefore, adults seek orthodontic treatment to improve their smile, occlusion, psychological well-being, and quality of life.[5,6] Orthodontic therapy pursues the objective of improving perceived aesthetics: for this reason, orthodontics is gaining popularity among and is partly attributable to the development of new technologies during the 70s and 80s. Many authors confirm that there is a growing number of adult patients who require orthodontic treatment.[7–10]

This factor, combined with the increase in the number of non-invasive facial aesthetic treatments, has led to the need to understand potential risk factors in the application of medical devices to the perioral skin in patients with fixed orthodontic appliances. The limit of temperatures reached by orthodontic appliances is objectively important because we know that a few degrees above the standard body temperature, which ranges from 36°C to 37°C, are sufficient to cause significant damage to the teeth. According to Hasegawa and colleagues, the temperature rise in dental devices is much lower than the 5.6°C safety limit for pulp tissue. Likewise, Ottl and Lauer demonstrate that 15% of dental pulps became necrotic when pulp chamber temperature increased by 5.6°C, and 60% became necrotic when temperature increased by 11.1°C.[11]

Pohto and Scheinin documented an increase in capillary permeability, which is the first sign of pulpal heat damage, when the temperature increased between 5°C and 7°C.[12] According to Eriksson and Albrektsson, the damage coefficient is also significant at the bone level, as exposure to temperatures of 44°C–47°C (7°C–10°C above body temperature) for 1 min is sufficient to cause alveolar bone necrosis. Ramsköld and colleagues demonstrate that raising the temperature can also be detrimental to the tissue adjacent to the tooth in the case of a 10°C increase for more than 60 s.[13] Zach and Cohen report that a 5.5°C temperature increase can cause irreversible pulpitis. In such cases, as documented by Lau XE and colleagues, when heat is transferred to the pulp, it can cause several histopathological alterations that can lead to irreversible damage.[14] Lin M et al. remind us that unlike heat transfer to other materials, the thermal behavior of teeth is a process of heat conduction, combined with physiological processes such as dentinal fluid and pulpal blood flow.[15] Consequently, dentinal fluid flow may enhance heat transfer within the pulp during temperature variations. Pulpal blood flow also influences the thermoregulation of soft pulpal tissues.[14] Pulpal blood flow is practically constant in the range between 33°C and 42°C, but increases significantly when the temperature exceeds 42°C.[16] Therefore, we can say that the mechanism of injury includes protoplasm coagulation, fluid expansion in dentinal tubules, increased outward flow from the tubules, vascular lesions, and tissue necrosis.[16–19] Sometimes, due to the variation in thermophysical properties and microstructure between layers of human teeth, heat transfer can also cause thermal stresses that lead to the formation of cracks within different layers.[15,20] In this study, we evaluated in vitro heating of the orthodontic bracket following electromagnetic fields and negative pressure (V-EMF) used as an anti-aging treatment.

2 | MATERIALS AND METHODS

We used two different types of titanium alloy wires, one made of "Beta-Titanium" alloy and the other "Ni-Ti" (DW Lingual Systems GmbH—Bad Essen—Germany) (Figure 1). The orthodontic wires and brackets mounted on a resin mouth were covered with porcine muscle tissue (1) and then subjected to anti-aging therapy with a Bi-one LifeTouchTherapy medical device (Expo Italia Srl—Florence—Italy) which generates a combination of vacuum and electromagnetic fields (V-EMF) already adopted for antiaging therapy.[21] During administration of the therapy, the orthodontic brackets and porcine tissue were thermally monitored using a Wavetek Materman TMD90 thermal probe (Willtek Communications GmbH—Germany). Prior to the measurements, the thermal probe was calibrated with a calibrated instrument, and the measurements were found to be accurate to within a tenth of a degree. The normal time for an anti-aging therapy with Bi-one LifeTouchTherapy for the face and neck is approximately 25 min, therefore the tissue/prosthesis combination was subjected to 25 min of administration, during which the temperature was measured in three points distinct on the face. the prostheses: in the center (B), at the molar level of the left arch (A), and at the molar level of the right arch (C). The ambient temperature was 24°/24.5°C and the orthodontic appliances were

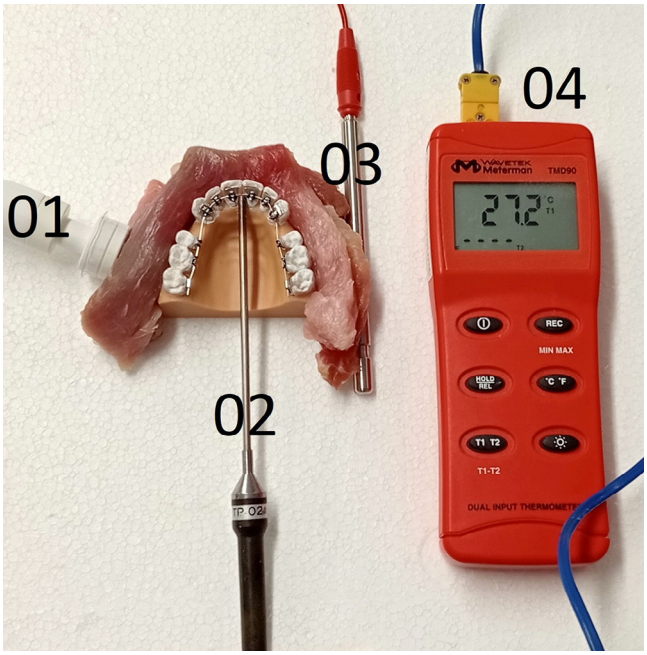

FIGURE 1 orthodontic wires and brackets mounted on a resin mouth were covered with porcine muscle tissue.

placed in contact with the porcine tissue 30 min before the treatment to align the temperature.[22] Measurements were taken at the three indicated points every 5 min. For the present study, it is considered acceptable and safe that a test detects a maximum increase in temperature of 2°C compared to the initial temperature at the end of the treatment, as prescribed by the CENELEC EN 45502-1 standard.

2.1 | Statistical evaluation

2.1.1 | Sample size analysis

The sample size calculation of the experiments was calculated through GPower software considering a total of two different groups and six measurements, according to an effect size f of 0.52, α error of 0.05 and a power of 80% by ANOVA a priori sample size compute test. The minimum sample size for statistical significance was 20 samples.

2.1.2 | Statistical methods

The analysis and graphical representation of the data output has been conducted by GraphPad 9 (Prism, San Diego, CA USA). The descriptive statistics has been calculated considering the means, standard deviations of the study groups. The Friedman test for repeated measures followed by Dunn's post hoc test has been conducted to evaluate the significance of the group's comparison. The temperature increase comparison has been tested through the non-parametric Wilcoxon test. The level of significance has been considered for $p < 0.05$.

3 | RESULTS

The measurements were performed by delivering V-EMF therapies to pig tissue in contact with orthodontic wires and brackets made of two different metal alloys. In total 20 orthodontic mouths were used, 10 with Beta Titanium wires and 10 with Nickel Titanium wires. In each group were recorded a 1°C increase of temperature. A temperature increases of about 1°C was recorded in each group. The temperatures recorded are summarized in Table 1 (Figures 2 and 3).

3.1 | Beta titanium group

The temperature measurements have been presented in Table 1. No significant differences have been detected comparing the intervals peaks considering the repeated measurements of the temperature detected in pig tissues and at the level of the brackets ($p < 0.05$). A significant difference has been observed after 25 min from the baseline comparing pig tissues temperature versus brackets surfaces with a means respectively of 0.81 ± 0.43 and 1.48 ± 0.5 ($p = 0.0137$) (Figures 2 and 3).

3.2 | Nichel-titanium group

No significant differences have been detected comparing the intervals peaks considering the repeated measurements of the temperature detected in pig tissues and at the level of the brackets ($p < 0.05$). A significant difference has been observed after 25 min from the baseline comparing pig tissues temperature versus brackets surfaces with a means respectively of 1.13 ± 0.75 and 1.10 ± 0.37 ($p < 0.05$), (Figures 2 and 3).

4 | DISCUSSION

From the data collected are noticeable that the absolute temperatures measured on orthodontic appliances, which, despite having a slightly different curve, both show an increase in temperature of 1.1°C at the end of the session, thus falling well within the safety range of 2°C as specified by the standard CENELEC EN 45502-1. Therefore, V-EMF therapy can be considered safe for the entire dental system and for metal prostheses,[23] which tend to heat up at most as much as biological tissue (+0.9°C/1.1°C vs. 1.1°C/1.1°C). Upon careful examination of the data, it is also noted that orthodontic appliances always reach a lower temperature compared to porcine biological tissue; it could therefore be inferred that the temperature increase may not be directly due to V-EMF therapy but rather to the dissipative action caused by the contact of the cooler orthodontic prosthesis with the warmer biological tissue, based on the principles of thermodynamics. Bone,[24] dental tissue, and dental pulp are extremely sensitive to thermal fluctuations, which can easily compromise the health of the dental pulp, the microcirculatory system that supplies it, and in some cases

TABLE 1 Summary of the descriptive statistics of the study data measurements.

Temperature (°C)		Baseline	5 MIN	10 MIN	15 MIN	20 MIN	25 MIN	Increase of temperature
Beta Titanium 18 × 25	Pig Tissue	23.2 ± 0.10	23.8 ± 0.3	23.9 ± 0.2	24 ± 0.4	24 ± 0.4	24.1 ± 0.4	0.81 ± 0.43
	Bracket	22.9 ± 0.13	23.4 ± 0.56	24.2 ± 0.56	24.2 ± 1.12	24.4 ± 0.51	24.4 ± 0.56	1.48 ± 0.5
p-value		*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* = 0.8445	*p* = 0.9087	*p* = 0.0137
Nichel-Titanium 18 × 25	Pig Tissue	23.50 ± 0.10°C	24.2 ± 0.66	24.2 ± 0.59	24.4 ± 0.51	24.5 ± 0.47	24.6 ± 0.73	1.13 ± 0.75
	Bracket	23.3 ± 0.1	23.9 ± 0.2	24.2 ± 0.2	24.2 ± 1.1	24.4 ± 0.2	24.4 ± 0.3	1.10 ± 0.37
p-value		*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* > 0.05	*p* > 0.05

FIGURE 2 Box and whiskers chart of the temperature measurements at the baseline, after 5, 10, 15, 20, and 25 min (min-max).

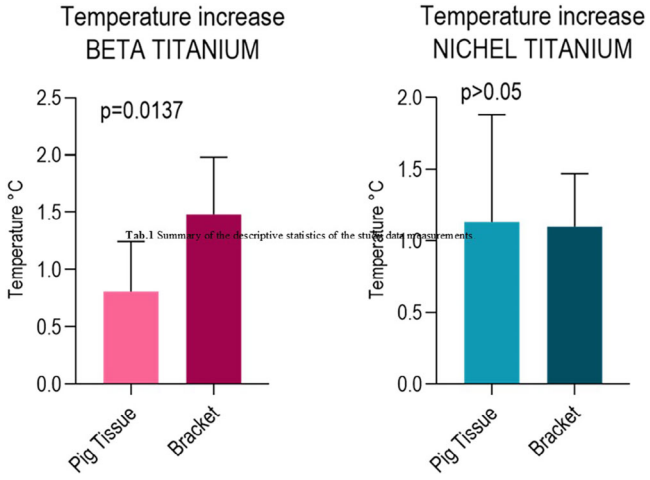

FIGURE 3 Summary diagram of the temperature increase after 25 min from the baseline [Wilcoxon test].

even lead to mechanical rupture. It has also been observed that several common anti-aging therapies cause a significant thermal shock to the skin tissue in direct physical contact with the teeth. According to the principles of thermodynamics, bodies at higher temperatures release thermal energy to colder bodies, thereby raising their temperature. Within the dental system, as human teeth are living tissue, the heat conduction process occurs simultaneously with physiological processes, including fluid movement in dentinal tubules and blood circulation in the pulp chamber.[14] Therefore, there is at least theoretically a risk that a high thermal effect on surrounding tissues caused by V-EMF therapy could potentially harm the dental pulp. Purschke and colleagues conducted an in vitro experiment where they heated a specific layer of cells, which were then brought into contact with another layer. The researchers found that heat exposure caused an increase in apoptosis (measured by apoptotic bodies and DNA condensation) in both heated and non-heated cells. Heating to 40°C–50°C increased apoptosis in the heated cell population up to eight times compared to baseline levels at 37°C.[25] Anti-aging therapies such as focused ultrasound, radiofrequency, and lasers expose the skin to extremely significant thermal stresses. According to Elsaie and colleagues[26] a radiofrequency-based therapy achieves the best results when the skin is heated to between 57°C and 61°C for a duration depending on the application area. Rodrigues de Araújo and colleagues found that during radiofrequency treatment, epidermal temperature is maintained at 40°C, while dermal temperature ranges from 50°C to 75°C.[27] Regarding focused ultrasound therapy, it is estimated that the device heats tissue to 65°C–75°C, the critical temperature at which collagen denaturation occurs triggering tissue repair cascade.[28,29] Similarly, ablative and non-ablative laser therapy causes collagen retraction and coagulation,[30–32] resulting in a skin temperature of 85°C with relatively prolonged exposure.[33,34] It has been shown that to achieve tissue coagulation and collagen contraction, the skin needs to be heated to 50°C–80°C.[35] Purschke et al. have demonstrated that at around 48°C, there is a plateau in the cell viability curve, while at temperatures above 56°C, there is a near-total loss of viability.[25] Blood is the best electrical conductor among biological tissues.[35,36] Therefore, in therapies that expose the skin to temperatures between 50°C and 80°C, there is a risk of overheating of surrounding tissues, requiring a more thorough clinical evaluation to demonstrate the absence of potential damage to the dental system and orthodontic prostheses, which could also impact the dental system itself.[14] The results of this work help aesthetic physicians understand how to use antiaging therapy with V-EMFs on patients wearing orthodontic appliances.

5 | CONCLUSION

In conclusion, anti-aging therapy with V-EMF causes a thermal increase on orthodontic brackets that is not harmful to pulp health. Therefore, V-EMF therapy can be safely performed in patients with fixed orthodontic appliances.

ACKNOWLEDGMENTS

The authors have nothing to report.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The investigation has been conducted in accordance with the Declaration of Helsinki and Good Clinical Practice Guidelines. The patients submitted the informed consent for the treatment and the anonymous data publishing.

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