Differences in Orthodontic Thermal Deflection of Nickel Titanium Wire in Artificial Saliva Soat And Isotonic Beverages

Budi Suhartono, Moh Yusuf**, Grahita Aditya***, Erdianto Setya Wardhana****,Eko Hadiyanto*****, Fathimah Fitria Sa'adah*******

*Department of Orthodontic, Faculty of Dentistry, Universitas Islam Sultan Agung
**Department of Oral Maxillofacial Radiology And Forensic, Faculty of Dentistry, Universitas Islam Sultan Agung
***Department of Orthodontic, Faculty of Dentistry, Universitas Islam Sultan Agung
****Department of Dental Public Health, Faculty of Dentistry, Universitas Islam Sultan Agung
*****Department of Dental Materials, Faculty of Dentistry, Universitas Islam Sultan Agung
******Dentistry Study Program, Faculty of Dentistry, Universitas Islam Sultan Agung

Correspondence: budisuhartono@unissula.ac.id

Received 20 February 2025; 1st revision 25 March 2025; 2nd revision 10 April 2025; Accepted 30 April 2025; Published online 30 April 2025

Keywords:

Orthodontic, Thermal Deflection, Nickel Titanium Wire, Saliva Soat, Isotonic Beverange

ABSTRACT

Background: *Deflection is one of the properties of the wire that can change if the environmental conditions in the oral cavity are acidic, caused by consuming isotonic drinks. This study aims to determine the difference in deflection of thermal nickel-titanium wire soaked in artificial saliva and isotonic drinks.*
Method: *The type of research used was an in vitro experimental analytic study with a post-only control group design method. The sample used was 36 thermal nickel titanium wire (American Orthodontics) with a wire size of 0.016 inches and divided into 2 groups consisting of the artificial saliva group and the isotonic drink group. Soaking was carried out for 10.5 hours and stored in an incubator at 37°C, then a deflection test was carried out using a Universal Testing Machine. Analysis of the results was carried out using the Independent T-Test in each group after treatment.*
Result: The results of the study using the Independent T-Test showed a significant difference in the deflection value of the thermal nickel titanium wire in the artificial saliva group and the isotonic drink group of 0.000 ($p<0.05$).
Conclusion: The conclusions obtained in this study indicate that thermal immersion of nickel-titanium wire in the artificial saliva group and the isotonic drink group affects the deflection force in orthodontic treatment.

doi: http://dx.doi.org/10.30659/odj.12.75-82
2460-4119 / 2354-5992 ©2025 National Research and Innovation Agency

Odonto : Dental Journal accredited as Sinta 3 Journal (https://sinta.kemdikbud.go.id/journals/profile/3200)
How to Cite: Suhartono *et al*. Differences in Orthodontic Thermal Deflection of Nickel Titanium Wire in Artificial Saliva Soat And Isotonic Beverages. Odonto: Dental Journal, v.12, n.1, p.75-82, April 2025

INTRODUCTION

Orthodontics is a branch of science in dentistry that studies the growth and development of the teeth and mouth and treatments to achieve normal occlusion.[1] According to Laguhi et al. (2014) abnormalities that occur in the teeth can affect the function of the oral cavity, one of which is malocclusion. Malocclusion is a tooth disorder that is not parallel to the dental arch or deviates from the normal state. Treatment that can be done in cases of malocclusion takes the form of orthodontic treatment. Such treatment can prevent the emergence of functional disorders in mastication, speech, and psychosocial areas. Orthodontic treatment has several objectives, namely restoring malpositioned teeth so that they can return to normal occlusion, preventing tissue damage, and improving orofacial esthetics and function.[2] The success of orthodontic treatment is influenced by several factors, such as the suitability of the treatment plan, the selection of orthodontic appliances, and operator competence. If one of the success factors for orthodontic treatment is not met, it will have an adverse impact, such as inflammation of the gingiva area, root resorption, and the occurrence of temporomandibular disorder (TMD).[3]

Orthodontic treatment consists of fixed orthodontic appliances and removable orthodontic appliances. Removable orthodontic appliances are simpler than fixed orthodontic appliances because they can be removed by the patient himself.[4] Removable orthodontic appliances are usually used for cases of disorders that are not complex.[5] In fixed orthodontic appliances, gluing is carried out so that they cannot be removed until the treatment is complete, which can only be done by a dentist. Fixed orthodontics has components consisting of brackets, bands, rubber power chains, rubber O rings, and bow wires made of stainless steel and nickel titanium.[6]

Orthodontic wire, as a component of fixed orthodontic appliances, is used to apply force to tooth movement.[7] In orthodontic treatment, it is necessary to apply light and continuous force in order to achieve good and optimal tooth movement.[8] The tooth movement referred to is in the form of an activation force (loading) received by the wire and a deactivation force (unloading), which will return the wire to its original shape accompanied by tooth movement in biological tissue.[9]

Orthodontic wire has a number of interesting properties, such as high springback ability, low stiffness, and the ability of the wire to adjust shape.[10] The requirement for wires at the initial stage of orthodontic treatment has minimum stiffness and maximum deflection properties.[11]

Orthodontic treatment needs to apply pressure to the orthodontic wire so that it is able to transmit the force that is distributed to the dentoalveolar area, resulting in tooth movement, known as the deflection force. From this deflection force, it is expected to have good tooth shifting abilities.[12] The wire is deflected due to the force exerted on the orthodontic wire. Triaminingsih (1996) stated that nickel-titanium wire has better deflection properties than other wires.

Success in fixed orthodontic treatment depends on the choice of wire to be used.[13] The wire that is often used for orthodontic treatment is nickel-titanium. Nickel-titanium wire was introduced in 1971 by Andreasen and Hileman.[14] Nickel-titanium wire has a composition of 55% nickel and 45% titanium.[15] Nickel-titanium wire has two properties, namely shape memory and high elasticity.[16]

Along with the discovery of materials in the field of orthodontics, nickel-titanium wire has various types, such as superelastic nickel-titanium wire and thermal nickel-titanium wire.[16] Thermal nickel-titanium wire has a composition of nickel and titanium; besides that, there is an additional composition of other metals in the form of copper and chromium. The addition of a metal composition to the wire causes the transition temperature to be controlled accurately, reduces friction, and increases material strength. The transition temperature on thermal nickel-titanium wire is from the active phase of maternite to the austenite form.[17]

Wires that interact with the oral environment, which is influenced by microorganisms, changes in temperature, acidity, and enzymes present in the oral cavity, will potentially experience the release of metal ions that make up the wire.[18] Orthodontic wire that is applied to the oral cavity will directly come into contact with saliva, so the wire material contained in the oral cavity will be affected by the oral environment in the form of food or drinks consumed, such as isotonic drinks.[19]

Isotonic drinks contain carbohydrates with a concentration of 6–9% and minerals with a concentration of 4–8% as a substitute for lost electrolyte ions.[20] Isotonic drinks contain sodium, potassium, and sucrose, which produce citric acid, phosphoric acid, malic acid, and tartaric acid.[21] Sodium chloride in isotonic packaged drinks is higher than in non-isotonic packaged drinks because it can restore lost body fluids and reduce urine loss due to moderate or severe dehydration and high sweat loss.[22] Sodium chloride is an electrolyte ion that can trigger electrochemical reactions.[23] Isotonic drinks have a pH of 2.4–4.5 below the critical pH limit.[24] The pH level of the isotonic drink consumed by fixed orthodontic users will release ions from the metals that make up the wire, and as a result, the wire will experience deformation so that it can change the characteristics of the wire.[12]

Several other studies, such as those conducted by Mahaddah, A., and Prijatmoko (2016) and Hasyim et al. (2016) showed that thermal nickel titanium wire immersed in drinks with an acidic pH, such as carbonated drinks and packaged tea drinks, will experience the release of ions on the wire, which will affect the resulting deflection of the wire.

RESEARCH METHOD

The type of research used in this study was laboratory experimental research with a post-test only control design. The subjects of this study used orthodontic thermal nickel-titanium wires. The number of samples used was determined using the Federer formula, and samples with a total of 16 were obtained. The number of samples was then added by 10%, and the results obtained were 36 samples. The research sample was divided into two groups, namely group I and group II. Samples in group I will be soaked using artificial saliva, and samples in group II will be soaked using isotonic drinks plus artificial saliva. Each sample group will then go through a deflection test. The research design will be described in the following scheme:

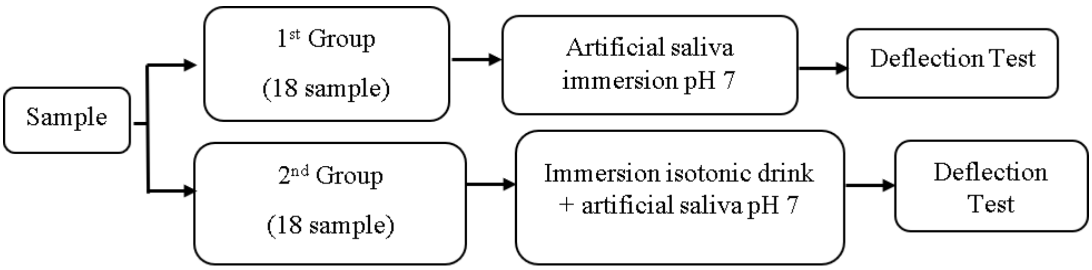

Figure 1. Sample Distribution

The work phase begins with preparing samples consisting of orthodontic nickel titanium wires (American Orthodontics) with a diameter of 0.016 inches and a length of 11.6 cm, totaling 36 pieces, which are then labeled with petradisks 1–18 for group I and petradisks 19–36 for group 2. Samples of artificial saliva solution and isotonic solution were given a dose of 29 ml each.

The sample immersion stage was determined based on the duration of one-time isotonic drink consumption; the results were 15 minutes multiplied by the duration of use of nickel-titanium wire in the oral cavity; the average usage was 6 weeks, so the immersion time was 10.5 hours. Group I will be immersed in 29 ml of normal pH 7 artificial saliva solution, and group II will be immersed in 29 ml of normal pH 7 artificial saliva plus 29 ml of isotonic drink. Each group will be put into a labeled petridisk package, then put in an incubator for 10.5 hours at a temperature of 37^{o}C.

After going through the immersion period, the sample will be dried in a desiccator to remove traces of the immersion solution and keep the sample moist. All samples will then go through a testing process with the three-point bending method using the Universal Testing Machine. The initial step of the test is carried out by placing the sample in a clamp, clamping it on both sides of the specimen, and giving a load with a point position in the middle of 1/2 L. The sample will be tested using a computer program that is connected to the Universal Testing Machine. The data results are determined based on the point that will give the wire a load until it is cut off. The results of the Universal Testing Machine tool are in the form of a monitor that shows the deflection value.

The results of the data will then go through a normality test using the Shapiro-Wilk test and a homogeneity test using Levene's Test. If the data obtained is normally distributed or homogeneous, then it is continued with a parametric statistical test (Independent T-Test), and if the data obtained is not normally distributed or homogeneous, then it is continued with a non-parametric statistical test (Mann Whitney).

RESULTS

Based on the results of the deflection test in this study, table 1 describes the average value of the 2 groups of thermal nickel titanium wire immersion in artificial saliva and isotonic drinks mixed with artificial saliva.

Table 1. The results of the mean value and standard deviation of the deflection force between the artificial saliva group and the isotonic drink group

Group	**Average** (mm)	**Standard deviation**
Artificial Saliva	14,40	2,80
Isotonic Beverage	10,57	1,44

Based on the results of the data in Table 1, it shows that the average deflection test on a wire that has been soaked in artificial saliva is 14.40 mm and the isotonic drink is 10.57 mm. The results of the data obtained from research on the effect of thermal nickel titanium wire that has been soaked with artificial saliva and isotonic drinks on the deflection force were then analyzed statistically. The normality test results using the Shapiro-Wilk test can be seen in Table 2. The artificial saliva group obtained a p value of 0.144 ($p > 0.05$), so the results of the data normality test showed that the data were normally distributed, and the isotonic drink group obtained a p value of 0.792 ($p > 0.05$), so the results of the data normality test show that the data are normally distributed. The overall results of each group show that the data is normally distributed and can be continued by carrying out a homogeneity test using Levene's Statistical test.

Table 2. Shapiro-Wilk Data Normality Test

Group	Sig.(P)	Definition
Artificial Saliva	0,144	Normal Data
Isotonic Beverage	0,792	Normal Data

The results of the analysis of the homogeneity test using Levene's Test are listed in Table 3, showing a p value of 0.014 (p> 0.05). If the data from each group shows that the data results are greater than 0.05, so that the variation between the artificial saliva group and the isotonic drink group is homogeneous, then it can be continued by conducting an unpaired t-test to find out whether there is a difference between the number of deflections in the wire thermal nickel titanium that has been soaked with artificial saliva and isotonic drink.

Table 3. Levene Data Homogenity Test

Levene test	**Sig.**	**Definition**
	0,014	Homogen Data

The results of the data from the unpaired t-test can be seen in Table 4.4. Unpaired t-test was used to determine the differences between the 2 groups in this study, namely the artificial saliva group and the isotonic drink group. The results of the analysis showed a (p) value of 0.00 (p <0.05), it could be concluded that there was a significant difference between the artificial saliva group and the isotonic drink group.

Table 4. Unpaired T-test results

Group	Avg. (mm)	Standard Deviation	Sig (2-tailed)
Artificial Saliva	14,40	2,80	0,000
Isotonic Beverages	10,57	1,44	

DISCUSSION

The purpose of this study was to determine the effect of thermal nickel-titanium wire soaked in artificial saliva and isotonic drinks on the deflection force. This study used 36 American Orthodontic thermal nickel-titanium wires. There were 2 groups, namely group I, in which the wires were soaked using artificial saliva and group II, in which the wires were soaked using isotonic drink, then stored in an incubator at 37ºC, and then deflection tests were carried out using the Universal Testing Machine (UTM).

Immersion performed on groups I and II was proven to affect the deflection results of orthodontic thermal nickel-titanium wire. The analysis test performed showed that there was a significant difference between the artificial saliva group and the isotonic drink group. The immersion group in artificial saliva obtained 14.40 mm results, and immersion in isotonic drinks mixed with artificial saliva had a deflection result of 10.57 mm, resulting in a decrease in deflection in the immersion treatment. This shows that the content and environment of the immersion solution can affect the resulting deflection of the thermal nickel-titanium wire. The results of this study are in accordance with research conducted by Mawaddah, A., and Prijatmoko (2016), which states that there is an effect of nickel-titanium wire soaked in carbonated drinks on the deflection force.

In group I, the thermal nickel-titanium wire was soaked using artificial saliva with a pH of 7. Saliva is a colorless liquid that has organic and inorganic components. The organic components are in the form of proteins, and the inorganic components are in the form of Na+, K+, Ca2+, Mg2+, Cl-, and H3PO4. One of the ingredients contained in artificial saliva is Cl- (chloride) ions as electrons, which can trigger the release of nickel ions from nickel titanium wire because it is included in the acid category, which can cause corrosion.[25]

Group II thermal nickel titanium wires were soaked using an isotonic drink containing Na+, K+, Ca2+, Cl-, C6H8O7, C3H6O3, and C4H6O6 with a pH of 4.6. One of the ingredients in isotonic drinks is NaCl (sodium chloride) and citric acid. Citric acid in isotonic drinks is used as a sour taste enhancer. NaCl is a salt that is formed in water to become an electrolyte solution and is categorized as a strong electrolyte group. Chloride ions can damage the oxide layer on the wire and are very aggressive in triggering the release of ions on the wire. In immersion, there is an interaction between Cl- (chloride) ions, which undergo a reduction reaction so that they can bind to the oxide layer released from nickel ions on the thermal nickel titanium wire. The release of ions that occurs can cause the wire to corrode.[26] The higher the chloride ion level, the higher the release of nickel ions on the thermal nickel titanium wire, which will cause a higher corrosion rate. Corrosion that occurs in thermal nickel-titanium wire can cause a decrease in the quality of the wire, which is marked by a decrease in the deflection of the wire.[21]

The acidic environment that occurs in isotonic drink immersion will cause a high increase in H+ (hydrogen) ions. This occurs because the H+ ions present in the immersion environment undergo a reduction reaction and then bind to electrons released from the oxidation reaction of nickel ions on the thermal nickel titanium wire. The more H+ ions, the higher the reduction reaction that occurs. Nickel ions, which act as anodes (oxidation), and H+ ions, which act as cathodes (reduction), will trigger the release of nickel ions, causing corrosion.[25] Environmental conditions in the acidic oral cavity can cause an increase in the release of metal ions.[23]

The release of metal ions on the thermal nickel-titanium wire is characterized by damage to the surface of the TiO2 (titanium oxide) layer, which is the outermost protective layer of the wire. After the outer layer of the wire is removed, the main ingredient of the wire, nickel, will experience oxidation and detach.[27] Nickel ions have a role as a material that is resistant to heat and provides flexibility to the wire. Oxidation that occurs in a wire material is an early sign of a decrease in the quality of the wire.[28]

Thermal nickel titanium wire material that has been immersed in an acidic environment will experience the release of nickel ions, which can cause damage to the wire, decrease in quality, and reduce safety. The release of nickel ions is a sign of corrosion on the wire and can affect the quality of the braces themselves.[29] Wire corrosion can cause discoloration on the metal surface, reduce strength, and cause allergic reactions in some orthodontic wire users.[26]

The choice of wire in the early stages of fixed orthodontic treatment must be considered, such as the composition of the wire used, the diameter of the wire, and the shape of the wire.[30] In this study, when the wire experiences too much nickel ion release because it is in an acidic environment, the strength and quality of the wire will decrease, causing the wire to experience a reduction in mass, which will reduce the properties and characteristics of the wire. The decrease in the quality of the wire that occurs will result in a decrease in the elastic properties of the wire, so that the deflection force generated by the thermal nickel-titanium wire will also decrease [11]. Orthodontic treatment requires the mechanical ability to move the teeth in order to produce proper tooth movement. A decrease in deflection force can result in inconstant tooth movement, which will result in less optimal tooth movement in orthodontic treatment and will require a longer treatment time.[31]

CONCLUSION

Based on the results of this study, it can be concluded that the deflection value of thermal nickel-titanium wire immersion in isotonic drinks is lower than that of artificial saliva immersion.

ACKNOWLEDGEMENT

The authors would like to thank various parties related to the implementation of this research at the Sultan Agung Islamic University Microbiology Laboratory (UNISSULA) and Engineering Materials Laboratory, Gadjah Mada University (UGM) and the Faculty of Dentistry at the Islamic University of Sultan Agung (UNISSULA) Semarang.

REFERENCES

1. H. N. Perwira, “Frekuensi kebutuhan perawatan ortodontik berdasarkan Index of Orthodontic Treatment Need di SMP Negeri 1 Salatiga,” *Jurnal Ilmu Kedokterran Gigi*, vol. 1, no. 1, pp. 1–11, 2017.
2. Herwanda, R. Arifin, and Lindawati, “Pengetahuan Remaja Usia 15-17 Tahun Di Sman 4 Kota Banda Acehterhadap Efek Samping Pemakaian Alat Ortodonti Cekat,” *J Syiah Kuala Dent Soc*, vol. 1, no. 1, pp. 79–84, 2016.
3. C. H. Khairusy, R. Adhani, and D. Wibowo, “HubunganTingkat Pengetahuan Responden Dengan Pemilihan Operator Selain Dokter Gigi Ditinjau dari Bahaya Pemasangan Alat Ortodontik,” *Dentino Jurnal Kedokteran Gigi*, vol. II, no. 2, pp. 166–169, 2017.
4. T. Alawiyah, “Komplikasi dan resiko yang berhubungan dengan perawatan ortodonti,” *Jurnal Ilmiah Widya*, vol. 4, no. 1, pp. 256–261, 2017.
5. T. Demmajannang and E. Erwansyah, “Gambaran indeks Bolton pada pasien yang dirawat dengan piranti ortodontik lepasan di Rumah Sakit Gigi Mulut Universitas Hasanuddin Overview of Bolton index on patients treated with removable orthodontic appliance in Dental Hospital of Hasanuddin Universit,” *Journal of Dentomaxillofacial Science*, vol. 12, no. 3, p. 175, 2013, doi: 10.15562/jdmfs.v12i3.374.
6. M. Nasir and Y. F. Ramadhany, “Tele-orthodontic as a recent solution in malocclusion treatment,” pp. 78–81, 2020, doi: 10.35856/mdj.v9i2.322.
7. R. Sekhar Kotha, R. Krishna Alla, M. Shammas, and R. Krishna Ravi, “An Overview of Orthodontic Wires,” *Trends Biomater. Artif. Organs*, vol. 28, no. 1, pp. 32–36, 2014, [Online].
8. C. Santiaji, Wetti Magdalena, Soekarsono Hardjono, “Pengaruh Jarak Dan Lama Peregangan Terhadap Besar Dan Penurunan Gaya Tarik Closed Coil Spring Nikel Titanium,” *Kedokteran gigi*, vol. 4, pp. 204–210, 2013.
9. J. M. Khatri and V. P. Mehta, “Evaluation of Force Deflection Properties of Various Types of Initial Orthodontic Archwires,” *J Indian Orthod Soc*, vol. 48, no. 4, pp. 309–312, 2014, doi: 10.5005/jp-journals-10021-1266.
10. S. M. Castro, M. J. Ponces, J. D. Lopes, M. Vasconcelos, and M. C. F. Pollmann, “Orthodontic wires and its corrosion - The specific case of stainless steel and beta-titanium,” *J Dent Sci*, vol. 10, no. 1, pp. 1–7, 2015, doi: 10.1016/j.jds.2014.07.002.
11. H. S. Hasyim, L. S. Devi, and A. Sumono, “Pengaruh Perendaman Kawat Nikel-Titanium Termal Ortodonti

dalam Minuman Teh Kemasan terhadap Gaya Defleksi Kawat (The Effect of Immersion Thermal Nickel-Titanium Archwire in The Bottled Tea Drinks to The Archwire Force Deflection)," *e-Jurnal Pustaka Kesehatan*, vol. 4, no. 2, p. 347, 2016.
12. C. A. Mawaddah, L. S. D. A., and D. Prijatmoko, "Perbedaan Defleksi Kawat Ortodonti Nikel-Titanium dan NiTi Epoxy Resin Coated pada Perendaman dalam Saliva Buatan dan Minuman Berkarbonasi," *Pustaka Kesehatan*, vol. 4, no. 3, pp. 519–524, 2016.
13. H. Aghili, S. Yasssaei, M. N. Ahmadabadi, and N. Joshan, "Load Deflection Characteristics of Nickel Titanium Initial Archwires.," *J Dent (Tehran)*, vol. 12, no. 9, pp. 695–704, 2015, [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/27148381%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4854749
14. P. Arifiani, "STUDI PUSTAKA Karakteristik kawat TMA (titanium molybdenum alloy) dan penggunaannya dalam perawatan ortodonti Putri Arifiani* dan Erwin Siregar**," pp. 163–171, 1979.
15. R. Sakaguchi, J. Ferracane, and J. Powers, *Craig's Restorative dental materials*, Fourteenth., vol. 71, no. 2. Elsevier Inc., 2012. doi: 10.1016/s0002-9416(77)90403-1.
16. E. Gatto, G. Matarese, G. Di Bella, R. Nucera, C. Borsellino, and G. Cordasco, "Load-defl ection characteristics of superelastic and thermal nickel-titanium wires," *Eur J Orthod*, vol. 35, no. 1, pp. 1–9, 2013, doi: 10.1093/ejo/cjr103.
17. S. Premkumar, *Textbook of ORTHODONTICS*. ELSEVIER, 2015.
18. A. Triawan, "Pengaruh Sel Galvanik Kawat Busur Ortodontik Cekat Australia dan Nikel Titanium dengan Amalgam terhadap Pelepasan Ion Nickel : Studi Laboratoris pada Lingkungan Saliva Tiruan dengan pH Normal," vol. 7, no. 2, pp. 69–75, 2010.
19. J. Misael, A. Suprihanto, and G. D. Haryadi, "Pengujian Laju Korosi Pada Perangkat Ortodontik Dengan Material Stainless Steel 316l Pada Penerapan Larutan," *Jurnal Teknik Mesin*, vol. 9, no. 2, pp. 205–214, 2021.
20. Y. Wulandari, Yuri and N. Suhartatik, "Stabilitas Minuman Isotonik Kelopak Bunga Rosela Ungu (Hibiscuss Sabdariffa) selama Penyimpanan," *JOGLO*, Vol. 28, no. 1, pp. 42–50, 2015, [Online]. Available: http://www.elsevier.com/locate/scp
21. N. p Wasono, Y. A. Assa, and P. s Anindita, "Pelepasan Ion Nikel Dan Kromium Bracket Stainless Stell Yang Direndam Dalam Minuman Isotonik," *E-Gigi*, Vol. 5, No. 1, Pp. 158–163, 2016, Doi: 10.35790/Eg.3.2.2015.10011.
22. M. R. G. Silva, T. Paiva, and H. H. Silva, *The impact of sports and energy drinks in performance*. Elsevier Inc., 2019. doi: 10.1016/B978-0-12-815851-7.00006-1.
23. M. M. Bonde and P. S. Anindita, "Uji Pelepasan Ion Logam Nikel (Ni) Dan Kromium (Cr) Kawat Ortodontik Stainless Steel Yang Direndam Dalam Air Kelapa," *Pharmacon*, vol. 5, no. 4, pp. 40–45, 2016.
24. N. Afrianti, I. Erlita, and R. Adhani, "Isotonic Beverage Effect on Surface Hardness of Bulkfill Type Composite Resin," *Dentino (Jur. Ked. Gigi)J Ked Gi*, vol. IV, no. 2, pp. 130–134, 2019.
25. A. Angeline, N. Djustiana, and N. Nazruddin, "<p>Perbedaan pelepasan ion nikel kawat SS ortodonti yang direndam dalam obat kumur ekstrak buah mengkudu (Morinda Citrifolia L.) dengan konsentrasi berbeda <p></p>Differences of the nickel ions release of orthodontic SS wire immersed in various concentrat," *Padjadjaran Journal of Dental Researchers and Students*, vol. 5, no. 2, p. 110, 2021, doi: 10.24198/pjdrs.v5i2.33407.
26. A. Kurniawan, T. D. Putra, and A. Farid, "Pengaruh Jumlah Plat Besi Terhadap Defleksi Pembebanan Pada Pengujian Superposisi," *Widya Teknika*, vol. 24, no. 2, pp. 1–5, 2016.
27. L. Casanova *et al.*, "Investigating the activation of passive metals by a combined in-situ AFM and Raman spectroscopy system: a focus on titanium," *Sci Rep*, vol. 13, no. 1, p. 6117, 2023, doi: 10.1038/s41598-023-33273-1.
28. B. Wibowo, J. Heryumani, and D. Dyah Karunia, "Pengaruh Besar Kompresi Dan Lama Perendaman Dalam Saliva Buatan Terhadap Kekuatan Open Coil Spring Nikel Titanium," *Jurnal Kedokteran Gigi*, vol. 6, no. 4, pp. 327–333, 2015.
29. Sumarji, "Studi Perbandingan Ketahanan Korosi Stainless Steel Tipe Ss 304 Dan Ss 201 Menggunakan Metode U-Bend Test Secara Siklik Dengan Variasi Suhu Dan Ph," *Jurnal ROTOR*, vol. 4, no. 1, pp. 1–8, 2011.
30. Gunawarman, Ilhamdi, V. Martin, J. Affi, and L. Aidil, "Karakteristik Mekanik dan Struktur Mikro Kawat

Titanium sebagai Fungsi Tingkat Deformasi untuk Aplikasi Restorasi Gigi," no. Snttm Xiii, pp. 15–16, 2014.
31. A. Wijaya, F. H. Nasution, R. Tjandrawinata, and Y. Yusra, "Perbandingan Komposisi Unsur Piranti Retensi Nikel Titanium dengan Nikel Titanium Superelastic dan Uji Sifat Kelelahan Logam," *Jurnal Teknik Mesin*, Vol. 2, no. 1, pp. 23–31, 2018.