EFFECT OF WATER TEMPERATURE AND WATER QUALITY ON SETTING TIME OF ALGINATE IMPRESSION MATERIALS

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Abstract. Alginate impression materials remain as an essential tool in dental practice. Setting time variability has long frustrated clinicians, particularly in tropical climates where water temperatures fluctuate significantly. This study examined how water temperature and quality affect alginate setting time using rheological measurement techniques, aiming to establish practical guidelines for clinical use. This study assessed the normal-setting alginate using a calibrated rheometer (300 Pa shear stress). Water temperatures of 2°C, 23°C, and 32°C were evaluated using distilled water. Tap water was also tested against distilled water at 23°C. One-way ANOVA was used to analyse temperature effects, while t-tests compared water types. Temperature dramatically influenced setting times: 99.36±0.30s at 2°C, 85.18±0.77s at 23°C, and 71.34±1.06s at 32°C ($p<0.001$). Water quality showed smaller effects: 90.86±1.65s for distilled water versus 86.52±2.46s for tap water ($p=0.178$). Water temperature significantly affects alginate setting time, with each 10°C increase reducing setting time by approximately 14%. Water quality showed minimal impact under study conditions. These findings support implementing temperature control protocols for optimizing alginate working time in clinical practice.
Keywords: *alginate, water temperature, impression materials, dental materials, hydrocolloids*

Introduction

Alginate impressions have survived decades of technological change in dentistry. While digital scanners has gained much popularity, these irreversible hydrocolloids offer unique advantages including cost-effectiveness, patient tolerance, ease of manipulation, and ability to capture detailed anatomical features in a single step (Dilip et al., 2017). Their clinical importance is evidenced by widespread use in prosthodontics, orthodontics, and general dental procedures for both preliminary and definitive impressions (Nandini et al., 2008; Ashley et al., 2005). As irreversible hydrocolloids, alginates contain more than 60% water in their gel form, making them highly sensitive to environmental conditions during mixing and setting (Fellows and Thomas, 2009; Anusavice, 2003). Alginate materials are highly sensitive to environmental factors, particularly water temperature and water composition during mixing. Recent research has evaluated the importance of these factors for optimizing clinical outcomes and ensuring consistent impression quality (Cervino, 2020; Pratiwi and Sutrisno, 2020). Water temperature sensitivity stems from the thermodynamic nature of the calcium-mediated cross-linking reaction that controls alginate gelation, while water quality effects arise from competitive ionic interactions that can interfere with controlled polymerization processes. The relationship between water temperature and alginate setting time follows well-established Arrhenius kinetics, where reaction rates increase exponentially with temperature due to increased molecular collision frequency and activation energy availability (Vallance, 2017; Wright, 2004). This temperature dependence has been consistently demonstrated across multiple studies, though methodological variations have led to some inconsistencies in quantitative

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findings. Early work by Indrani and Matram (2013) established an inverse correlation between water temperature and setting time across a range of 13°C to 28°C, thus providing foundational evidence for temperature-dependent behavior. Recent studies have provided more precise quantification of these effects. Pratiwi and Sutrisno (2020) reported a 23.2% reduction in setting time when water temperature is increased from room temperature (±24°C) to ±40°C. Their findings confirmed the significance of temperature control for clinical applications.

The molecular mechanism underlying temperature effects involves the kinetic energy available for calcium ion diffusion and cross-linking with guluronic acid blocks within alginate polymer chains. Higher temperatures facilitate more rapid ion mobility and increase the frequency of effective binding events, accelerating the formation of the characteristic "egg-box" structure that provides gel stability (Wawszczak et al., 2024). This understanding has direct clinical implications, as controlled temperature manipulation offers a practical method for adjusting working time to accommodate varying procedural requirements. Material storage conditions also influence alginate setting behavior, with extended storage potentially altering powder reactivity and setting characteristics (Rahmadina et al., 2017). Alginate manufacturers universally recommend distilled or demineralized water for mixing, yet clinical practice often utilizes tap water of variable quality that may not meet optimal purity standards (WHO, 2004). The presence of dissolved ions, such as calcium and magnesium, can significantly alter alginate setting characteristics through competitive interactions with the intended cross-linking mechanism (Raszewski et al., 2018). Recent mechanistic studies have elucidated the molecular basis for these water quality effects. Raszewski et al. (2018) demonstrated that specimens mixed with calcium-containing water exhibited increased hardness and Young's modulus values compared to those prepared with distilled water, indicating that ionic composition affects not only setting kinetics but also final mechanical properties. The presence of environmental cations can initiate premature cross-linking reactions, disrupting the controlled setting process engineered by manufacturers. Understanding these material science principles is essential for optimizing clinical procedures and ensuring consistent impression quality (Greig, 2012). Most dental practices rely on ambient tap water without consideration of seasonal temperature variations or local water quality characteristics. The tropical climate prevalent in Malaysia presents particular challenges, with tap water temperatures often exceeding 30°C during hot weather conditions. This elevated water temperature often accelerate alginate setting, potentially compromising working time and impression quality. The objective of this study was to investigate the effects of water temperature and water quality on alginate setting time using advanced rheological measurement techniques. Understanding these relationships is essential for developing practical clinical guidelines that can optimize impression procedures while minimizing material waste and procedural complications.

Materials and Methods

Study design and location

The laboratory experiments was conducted at the International Islamic University Malaysia, Kuantan campus. The study comprised of two phases: temperature effects using distilled water, and water quality comparison at constant temperature. Each experiment was replicated three times to ensure statistical validity.

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Alginate

Normal-setting irreversible hydrocolloid alginate impression material (Kromopan, Lascod, Italy) mixed according to manufacturer specifications (23g powder to 50ml water). Fresh powder from unopened containers prevented storage-related degradation.

Water preparation

Distilled water was sourced from laboratory suppliers with verified purity. Tap water samples were collected fresh from laboratory tap and used within 24 hours. Different water temperature was measured using digital thermometer (HM Digital, Spain) with accuracy of ±0.1°C.

Rheometer

Rheological measurements were performed using a Thermo Scientific HAAKE Modular Advanced Rheometer System (MARS) (Massachusetts, USA). The rheometer was calibrated according to manufacturer specifications before each experimental session.

Setting time measurement protocol: Rheometric method

The rheometer applied constant shear stress to alginate samples while monitoring viscosity changes throughout the polymerization process. Preliminary baseline experiments determined optimal measurement conditions by testing shear stress levels at 100, 300, and 500 Pa. Each condition was evaluated for ability to replicate manufacturer-specified setting times (target: 115±10 seconds total setting time). The 300 Pa condition yielded measured setting times of 79.21±2.1 seconds (excluding 40-second working time), representing the closest approximation to manufacturer specifications and was therefore selected for all subsequent measurements. As the alginate becomes more solid over time, the ability of the spindle to shear the setting alginate decreases. This is called shear rate, $\dot{\gamma}$. As the alginate sets, the shear rate (the shearing capacity towards the alginate) will decrease. The shear rate was measured in inverse second (1/s) and the time taken for the shear rate to record “0” indicates the setting time of alginate. *Figure 1* and *Table 1* showed the different shearing force tested to achieve the closest setting time to manufacturer’s recommendation.

Table 1. *Comparison of time taken for shear stress to approach “0”*.

Test	Shearing force	Time for shear rate to reach “0” (s)
1	100 (Green)	86.42
2	300 (Red)	79.21
3	500 (Blue)	89.10

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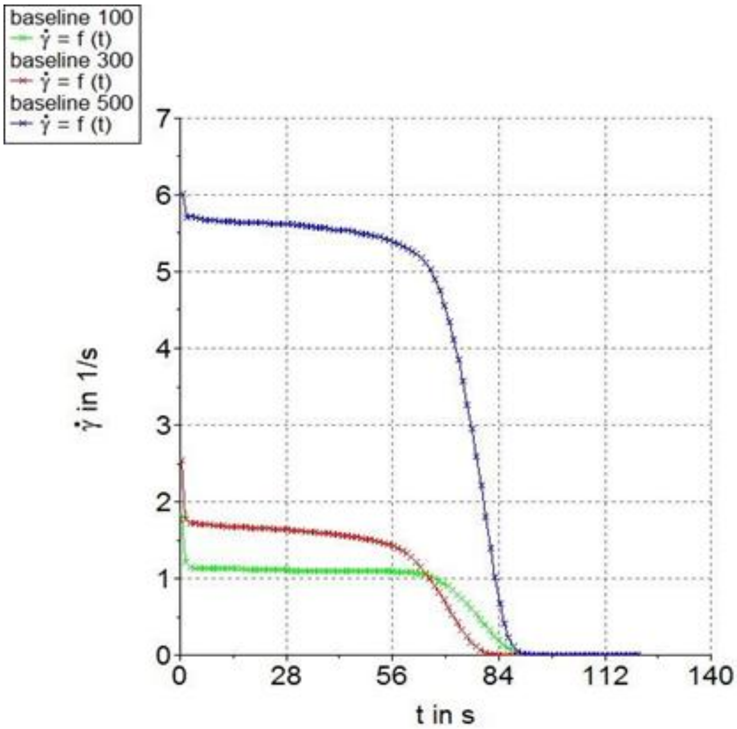

Figure 1. *Baseline graph to determine shear stress.*

Sample preparation protocol & statistical analysis

For each measurement, alginate powder was mixed with water for exactly 10 seconds using an alginate mixer (Motion MX-300, Zhermack, Italy). Immediately following mixing, 1.0 ml of alginate was loaded onto the rheometer plate using a calibrated micropipette. Total working time for the material to set completely was recorded. Phase 1 (temperature effects): The type of water used during this phase was kept constant which was distilled water. The different water temperature was prepared at 2ºC, 23°C and 32 °C. Phase 2 (water quality): The alginate was prepared using two different water types, which was tap and distilled water. The temperature for both tap and distilled water was kept constant at 23ºC. Data analysis was performed using SPSS version 23.0 (SPSS Inc., Chicago, USA). Descriptive statistics (mean±standard deviation) were calculated for all experimental conditions. The data normality was verified using Shapiro-Wilk tests. One-way analysis of variance (ANOVA) was used to assess significant differences between temperature groups, followed by Tukey's post hoc testing for multiple comparisons. Independent samples t-test compared water quality conditions. Statistical significance was established at $p<0.05$ for all analyses.

Results and Discussion

Table 2 displayed descriptive statistics for all experimental conditions. Water temperature demonstrated an inverse relationship with alginate setting time, with mean values ranging from 71.34±1.06s at 32°C to 99.36±0.30s at 2°C. Water quality comparison revealed mean setting times of 90.86±1.65s for distilled water versus 86.52±2.46s for tap water. One-way ANOVA revealed highly significant differences between temperature groups ($p<0.001$). Post hoc analysis using Tukey's HSD demonstrated significant pairwise differences between all temperature conditions

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($p<0.001$ for all comparisons) (*Table 3*). Linear regression analysis revealed a strong negative correlation between temperature and setting time ($r=-0.984$, $p<0.001$). The temperature coefficient indicated approximately 0.94 seconds decrease in setting time per degree Celsius increase, representing a 1.1% change per degree at room temperature baseline. Independent samples t-test comparing distilled water versus tap water revealed no statistically significant difference in setting times ($p=0.178$) (*Table 4*). Coefficient of variation analysis revealed greater measurement variability for tap water conditions (CV=2.84%) compared to distilled water (CV=1.82%), suggesting less consistent setting behavior with tap water despite similar mean values. *Figure 2* demonstrated clear separation of rheological curves between temperature conditions, with distinct shear rate decay profiles corresponding to different polymerization kinetics. Lower temperatures exhibited extended decay curves, reflecting prolonged gelation processes. *Figure 3* showed subtle but consistent differences between water quality conditions, with tap water demonstrating slightly more rapid initial viscosity increase.

***Table 2**. Descriptive statistics for alginate setting time.*

Condition	Mean±SD (s)	CI	CV (%)
Temperature Effects (Distilled Water)			
2°C	99.36 ± 0.30	98.9-99.7	0.30
23°C	85.18 ± 0.77	84.2-86.1	0.90
32°C	71.34 ± 1.06	70.0-72.8	1.49
Water Quality Effects (23°C)			
Distilled Water	90.86 ± 1.65	88.5-93.2	1.82
Tap Water	86.52 ± 2.46	83.1-89.8	2.84

Note: SD=Standard Deviation; CI=Confidence Interval; CV=Coefficient of Variation

***Table 3**. One-way ANOVA for different water temperatures.*

Water temperature	Mean alginate setting time (SD)	F statistic (df)	p-value
32ºC	71.3 (1.06)	326 (2)	0.000**
23ºC	85.2 (0.77)		
2ºC	99.4 (0.30)		

*Note: **p<0.001.*

***Table 4**. One-way ANOVA between distilled and tap water.*

Water quality	Mean alginate setting time (SD)	F statistic (df)	p-value
Distilled water	90.9 (1.65)	2.129 (1)	0.218
Tap water	86.5 (2.46)		

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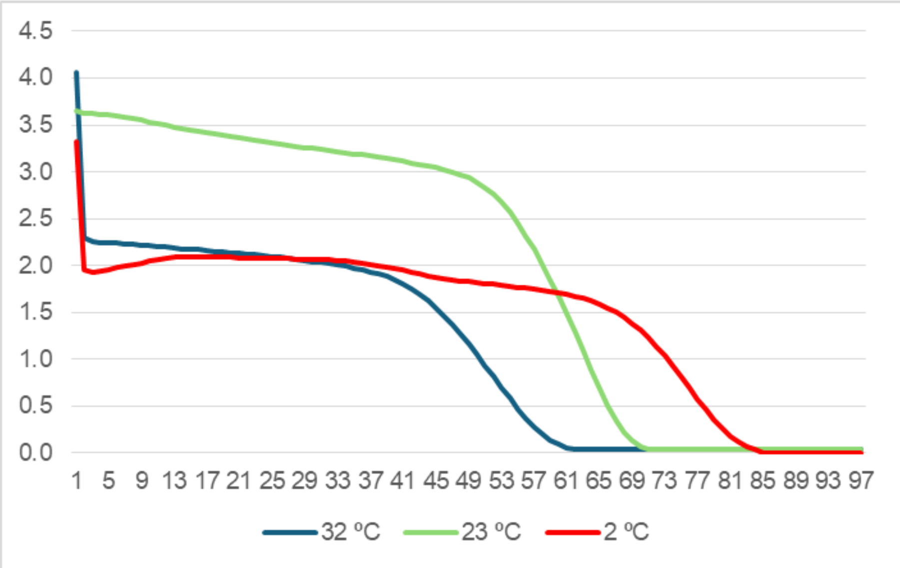

Figure 2. *Shear rate vs time for water temperature of 2ºC, 23ºC and 32ºC.*

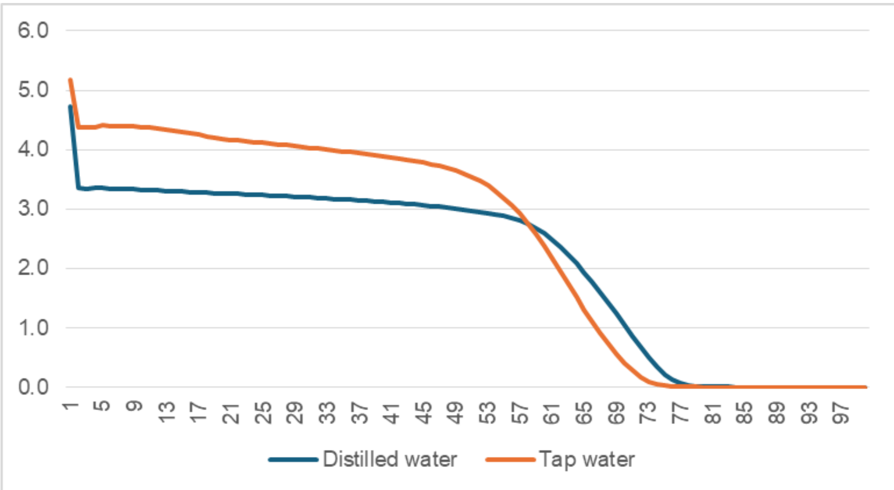

Figure 3. *Shear rate vs time for distilled and tap water.*

This study investigated how water temperature and water quality affect alginate setting time using rheological analysis. Our findings reveal significant relationships between both parameters and alginate polymerization. These results have important implications for clinical dental practice and quality control protocols. Alginate is an irreversible hydrocolloid. It undergoes a sol-gel transformation when it reacts with water. Sodium or potassium alginate and calcium sulfate make up the primary components, while trisodium phosphate serves as a retarder to control reaction kinetics (Anusavice, 2003). The setting reaction involves dissolution of soluble alginate salts, followed by cross-linking with calcium ions to form insoluble alginate gel networks. At the molecular level, sodium or potassium ions are replaced by calcium ions, creating cross-linked polymer networks through the characteristic "egg-box" structure formation between guluronic acid blocks and divalent calcium ions (Wawszczak et al., 2024; Lee and Mooney, 2012). The controlled release of calcium ions from calcium sulfate, initially sequestered by trisodium phosphate, determines the overall reaction rate and final setting time. The dimensional stability of these hydrocolloid networks depends on maintaining proper water content and avoiding deformation during initial setting phases

(Song-Qin, 2012). Our rheometer methodology used a constant shear stress of 300 Pa. We selected this value through systematic baseline testing at three levels: 100 Pa, 300 Pa, and 500 Pa. This is to identify conditions that most closely replicated manufacturer-specified setting times. Several advantages emerge from this approach compared to traditional penetrometer methods. We can monitor viscosity changes continuously. Subjective endpoint determination biases are eliminated. Our rheometer measures progressive increases in material resistance to deformation. Setting time gets defined as the point where shear rate approaches 0.1 s^{-1}, representing practical gel formation. Recent studies have validated rheological approaches for alginate characterization. King et al. (2008) demonstrated that complex modulus measurements provide superior accuracy for tracking polymerization kinetics. Traditional rod-dipping methods can't match this precision. Our methodology aligns with contemporary rheological standards for dental impression materials. It offers improved reproducibility compared to conventional techniques (Nallamuthu et al., 2012).

Water temperature and alginate setting time follow well-established Arrhenius kinetics principles. Lower water temperatures reduce molecular kinetic energy. This decreases the frequency of effective collisions between reactive species according to collision theory fundamentals (Wright, 2004). Setting time gets prolonged as a result. On the other hand, higher temperatures work differently. They increase molecular motion and collision frequency by accelerating cross-linking reactions, thus reducing setting time. This temperature dependence aligns with collision theory, where reaction rate increases exponentially with temperature. More molecules possess sufficient activation energy for successful chemical reactions (Vallance, 2017). Recent experimental evidence closely matches our findings. Pratiwi and Sutrisno (2020) reported a 23.2% reduction in setting time when water temperature increased from room temperature (24°C) to 40°C. They used standardized penetrometer methods according to ANSI/ADA No. 18 specifications. Setting times in their study were 119.4 seconds at 15°C compared to 87 seconds at 40°C. This confirms the inverse relationship between temperature and setting time across different measurement methodologies. Indrani and Matram (2013) also made similar observations. They found an inverse correlation (r=-0.968) between water temperature and setting time across a range of 13°C to 28°C. These findings support fundamental thermodynamic principles governing alginate polymerization. Clinical implications of temperature effects are significant for dental practice. Controlled water temperature adjustment provides a practical method for modifying alginate working time. Different clinical procedures and patient needs can be accommodated. Cooler water temperatures extend working time for complex impressions or challenging patient situations, whereas warmer water accelerates setting for routine procedures requiring faster turnaround times. Water quality used for alginate mixing significantly influences setting characteristics and final material properties. Distilled water remains the gold standard for alginate preparation. Manufacturers recommend it due to its predictable ionic composition and absence of interfering cations. Tap water presents challenges as it contains variable concentrations of dissolved ions, particularly calcium and magnesium from the second group of the periodic table. These ions can interact with alginate chains and alter polymerization kinetics. Raszewski et al. (2018) conducted important research on this topic. Specimens mixed with calcium-containing water exhibited greater hardness and higher Young's modulus values. Recent advances in alginate material science have further elucidated these ionic interaction mechanisms (Hamrun et al., 2022). Additional cations accelerate

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initial gel formation by providing alternative cross-linking sites. However, this can also lead to irregular polymer network formation and altered material properties. Competing ionic interactions interfere with the controlled calcium release mechanism that governs normal alginate setting, which explains the phenomenon we observed.

Calcium ions from the controlled sulfate source compete with environmental cations from water. Metal ions, particularly divalent cations like calcium and magnesium, can react directly with negatively charged carboxylic groups on alginate chains. Premature or irregular cross-links form that disrupt the intended polymerization sequence (Bradna and Cerna, 2006). Heterogeneous gel formation results. Both setting time predictability and final impression accuracy can be compromised. Studies utilizing advanced characterization techniques have confirmed that water quality affects more than just setting time. Dimensional stability, mechanical properties, and long-term impression accuracy are also impacted (Cervino et al., 2018). Extended storage of alginate impressions presents additional considerations, as dimensional changes continue over time even under optimal storage conditions (Walker et al., 2010). The powder-to-water ratio also significantly influences final impression properties, with variations affecting not only setting time but also tear strength and detail reproduction capabilities (Abdelraouf et al., 2021). Our study findings directly impact dental practice protocols and quality assurance procedures. Temperature control during alginate preparation offers a practical method for customizing material behavior to specific clinical requirements. Dental practices should consider implementing standardized water temperature protocols. This becomes particularly important in environments with significant ambient temperature variations. It's also crucial when consistent impression timing is critical for workflow efficiency. These protocols are particularly relevant for complete denture impression procedures where precise timing is essential (Carlsson et al., 2013). Water quality standardization represents another important quality control measure. Using distilled or demineralized water eliminates variables associated with local water composition. This becomes particularly important in areas with hard water or high mineral content. Tap water use in these locations may compromise impression accuracy and consistency. This study focused on setting time as the primary outcome measure. Rheological analysis provided continuous monitoring of polymerization progress. This approach offers advantages in terms of objectivity and reproducibility. However, correlation with traditional clinical assessment methods warrants further investigation. Future research should also assess other water quality parameters, such as pH and specific ionic compositions, would provide additional insights for optimizing alginate performance.

Conclusion

Both water temperature and water quality significantly influence alginate setting time. Well-established thermodynamic and chemical principles control these effects. Lower temperatures and interfering ions in tap water prolong setting time. Higher temperatures and distilled water promote faster, more predictable polymerization. This rheological approach provides objective, reproducible measurement of these effects. It offers advantages over traditional subjective assessment methods. These findings support implementing standardized protocols for water temperature and quality control in dental practices

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

REFERENCES

[1] Abdelraouf, R.M., Bayoumi, R.E., Hamdy, T.M. (2021): Effect of powder/water ratio variation on viscosity, tear strength and detail reproduction of dental alginate impression material (In vitro and clinical study). – Polymers 13(17): 11p.

[2] Anusavice, K.J. (2003): Phillips' Science of Dental Materials. – Elsevier Health Sciences 832p.

[3] Ashley, M., McCullagh, A., Sweet, C. (2005): Making a good impression:(a'how to'paper on dental alginate). – Dental Update 32(3): 169-175.

[4] Bradna, P., Cerna, D. (2006): Impact of water quality on setting of irreversible hydrocolloid impression materials. – The Journal of Prosthetic Dentistry 96(6): 443-448.

[5] Carlsson, G.E., Örtorp, A., Omar, R. (2013): What is the evidence base for the efficacies of different complete denture impression procedures? A critical review. – Journal of Dentistry 41(1): 17-23.

[6] Cervino, G. (2020): Impression materials: does water affect the performance of alginates? – Minerva Stomatologica 69(2): 106-111.

[7] Cervino, G., Fiorillo, L., Herford, A.S., Laino, L., Troiano, G., Amoroso, G., Crimi, S., Matarese, M., D'Amico, C., Nastro Siniscalchi, E., Cicciù, M. (2018): Alginate materials and dental impression technique: A current state of the art and application to dental practice. – Marine Drugs 17(1): 15p.

[8] Dilip, A., Gupta, R., Geiger, Z. (2017): Dental Alginate Impressions. – StatPearls Publishing 5p.

[9] Fellows, C.M., Thomas, G.A. (2009): Determination of bound and unbound water in dental alginate irreversible hydrocolloid by nuclear magnetic resonance spectroscopy. – Dental Materials 25(4): 486-493.

[10] Greig, V. (2012). Craig's restorative dental materials. – British Dental Journal 1p.

[11] Hamrun, N., Talib, B., Ruslin, M., Pangeran, H., Hatta, M., Marlina, E., Yusuf, A.S.H., Saito, T., Ou, K.L. (2022): A promising potential of brown algae Sargassum polycystum as irreversible hydrocolloid impression material. – Marine Drugs 20(1): 9p.

[12] Indrani, D.J., Matram, N. (2013): Changes in setting time of alginate impression material with different water temperature. – Dent J (Majalah Kedokteran Gigi) 46(1): 5-8.

[13] King, S., See, H., Thomas, G., Swain, M. (2008): Determining the complex modulus of alginate irreversible hydrocolloid dental material. – Dental Materials 24(11): 1545-1548.

[14] Lee, K.Y., Mooney, D.J. (2012): Alginate: properties and biomedical applications. – Progress in Polymer Science 37(1): 106-126.

[15] Nallamuthu, N.A., Braden, M., Patel, M.P. (2012): Some aspects of the formulation of alginate dental impression materials-Setting characteristics and mechanical properties. – Dental Materials 28(7): 756-762.

[16] Nandini, V.V., Venkatesh, K.V., Nair, K.C. (2008): Alginate impressions: A practical perspective. – Journal of Conservative Dentistry and Endodontics 11(1): 37-41.

[17] Pratiwi, D., Sutrisno, J.A. (2020): Water temperature's effects towards setting time of normal type alginate impression material. – Journal of Indonesian Dental Association 3(2): 103-107.

[18] Rahmadina, A., Triaminingsih, S., Irawan, B. (2017): The influence of storage duration on the setting time of type 1 alginate impression material. – In Journal of Physics: Conference Series, IOP Publishing 884(1): 4p.

[19] Raszewski, Z., Nowakowska-Toporowska, A., Weżgowiec, J., Nowakowska, D. (2018): Effect of water quantity and quality on the properties of alginate impression materials. – Dental and Medical Problems 55(1): 43-48.

[20] Song-Qin, L.I.U. (2012): Effect of composition of alginate impression material on "recovery from deformation". – International Journal of Chemistry 2: 81-89.

[21] Vallance, C. (2017): An Introduction to chemical kinetics. – Morgan & Claypool Publishers 56p.

[22] Walker, M.P., Burckhard, J., Mitts, D.A., Williams, K.B. (2010): Dimensional change over time of extended-storage alginate impression materials. – The Angle Orthodontist 80(6): 1110-1115.

[23] Wawszczak, A., Kocki, J., Kołodyńska, D. (2024): Alginate as a Sustainable and Biodegradable Material for Medical and Environmental Applications-The Case Studies. – Journal of Biomedical Materials Research Part B: Applied Biomaterials 112(9): 22p.

[24] World Health Organization (WHO) (2004): Guidelines for drinking-water quality. – WHO 668p.

[25] Wright, M. (2004): Theories of chemical reaction-collision theory in an introduction to chemical kinnetics. – John Wiley & Sons 462p.

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