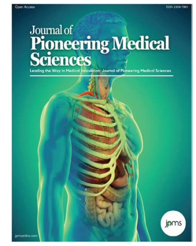

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Comparative Analysis of Dimensional Accuracy in the Integration of Different Setting Times of Impression Materials

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Abstract **Background:** Dental impressions are essential in restorative and prosthetic dentistry, as their accuracy directly impacts the fit and functionality of dental prostheses. The selection of impression material and its corresponding setting time plays a crucial role in determining final dimensional precision. This in vitro study aimed to assess the dimensional accuracy of dental impressions created using various combinations of impression materials with different setting times, providing evidence-based guidance for clinicians in selecting optimal and reliable material combinations. **Materials and Methods:** A total of 72 samples were divided into three groups: Fast-Fast (light body fast-set and regular body fast-set), Fast-Normal (light body fast-set and regular body normal-set) and Normal-Fast (light body normal-set and regular body fast-set). Impressions were taken from a typodont using polyvinyl siloxane (Aquasil Ultra, Dentsply Sirona). Digital impressions were created using a Zirkonzahn scanner and superimposed onto a digital reference cast. Six parameters related to height and width were measured using Exocad software. **Results:** Statistically significant differences were found between the groups for buccal ($p = 0.0002$), mesiodistal ($p = 0.0002$) and buccopalatal ($p = 0.006$) dimensions. The Fast-Normal group exhibited significantly higher mean values for these parameters than did the Fast-Fast and Normal-Fast groups. **Conclusions:** Mixing fast set and normal set time impression materials changed the measurements slightly. The combination of impression materials with different setting times significantly affected dental impressions, particularly the buccal, mesiodistal and buccopalatal dimensional aspects. These findings suggest that careful consideration of impression material properties, such as setting time, is crucial to ensure the dimensional accuracy and optimal fit of prosthetic restorations. **Clinical Significance:** This research aims to evaluate and validate alternative impression methods for clinical cases where material availability is limited, by comparing the dimensional accuracy of dental impressions made with different material combinations. Through rigorous assessment of accuracy measurements and significant differences between various material combinations, the study seeks to provide evidence-based solutions that address the practical challenges of material accessibility and availability in dental clinics. This research will ultimately help dental practitioners make informed decisions about impression material selection when faced with supply limitations, ensuring they can maintain clinical standards while working with alternative material combinations that have been proven to deliver acceptable accuracy.

Key Words Dental impressions, dental prosthetics, dimensional accuracy, setting time

INTRODUCTION

Dental impressions are conventionally obtained using specific materials and employed to replicate the teeth, gums and surrounding oral tissues to reproduce accurate prostheses. Numerous studies have been conducted on impression materials; however, these studies have focused on the utility of elastomeric impression materials [1]. Although rubber-based materials have been developed, elastomeric substances are often used when precision is of utmost importance. The commonly used elastomeric substances include polysulfide, condensation silicone, polyether (PE) and addition silicone polyvinyl siloxane

(PVS). To date, no impression substance has achieved absolute accuracy [3]. Moreover, impression accuracy is influenced by various factors, including dentist experience, impression technique, material manufacturer, tray selection, material working time and patient compliance [4]. All impressions should be carefully evaluated for accuracy, particularly in the finishing line area [5].

Elastomeric impression materials are the preferred options for fixed prosthodontics owing to their unique characteristics, including the capacity to diminish marginal voids and distortions [6] (Table 1) for elastomers materials properties. Until recently, the options for elastomers were primarily dependent on two reliable choices: Either PE or polyvinyl siloxane (PVS). Addition silicone, commonly referred to as PVS, is divided into four categories based on its consistency: Light, medium, heavy and putty. PVS is versatile and one of the most widely used impression materials in the dental field, offering predictable and accurate results as well as ultimate patient satisfaction [7]. It offers notable benefits including remarkable dimensional stability, minimal polymerization shrinkage, high tear strength and outstanding elastic recovery [8]. Alternatively, PEs offer moderate stability and good accuracy [9], making PE impression materials hydrophilic, which improves material flow and tooth structure reproduction [10]. However, PE has the following limitations: it is expensive; has low tear strength, making it difficult to remove from the patient's mouth; and may cause allergic reactions [8,11].

As no single impression material fulfills all desired requirements, researchers have attempted to combine commonly used materials [12]. To this end, the mechanical properties of a recently developed elastomeric impression material, which is a combination of vinyl polysiloxane (VPS) and PE, called polyvinyl ether silicone (PVES) were evaluated. The new material was evaluated by measuring the dimensional changes in the cast and comparing them with the reference model. In addition, two balls were added to the lingual and occlusal surfaces to measure any changes in distance. The new material showed results similar to those of regular impression materials [10]. Despite the limitations of the study, PVES exhibited high flexibility and tens ile strength, suggesting that this material is particularly suitable for undercut areas because it facilitates the removal of impressions without causing tears or distortions [6].

Another major challenge in impression-making is the long intraoral setting time, ranging from 5 to 7 min for most impression materials [10]. Fast-setting elastomeric impression materials have been developed to reduce setting time and enhance patient experience. These materials allow quicker and more efficient procedures and show improved flowability and low viscosity, which facilitates the accurate capture of fine details [13]. Singer *et al.* [14] conducted an analysis in which they employed a variety of tools to assess dimensional alterations. To ensure accuracy, each sample was examined under a stereomicroscope (Leica Microsystems, Wetzlar, Germany). The primary objective of this examination was to verify the consistent presence of a 75-µm line in every specimen. Dimensions were measured using a Carl Zeiss stereomicroscope at a magnification of 12×. The impressions materials were divided into fast and normal based on their setting times. Therefore, dentists have several choices of impression materials depending on preference or availability of the material in the clinic or market. According to accessibility and availability, some dentists attempt to make impressions using different setting times, which may affect the dimensional accuracy and marginal fit of the prosthesis.

Previous studies focused on comparing different types of elastomeric impression materials, such as combining PVS and PE; however, the effect of combining impression materials with different setting times has not been established in the literature. This represents a clear gap in the literature, especially since such combinations could be useful in everyday dental practice, including those with limited resources. This *in vitro* study aimed to investigate the impact of combining different setting times on impression accuracy.

Objectives

This study aimed to assess the impact of different setting times of impression materials on accuracy and consistency in clinical applications. The null hypothesis posits that varying setting times do not influence the accuracy of impression materials, while the alternative hypothesis suggests that differences in setting times lead to variations in accuracy.

MATERIALS AND METHODS

Samples

This in vitro study was conducted from February 1, 2024, to March 28, 2024, at the Prosthetic Laboratory, Faculty of Dentistry, King Abdulaziz University. A power analysis was performed utilizing the most recent version of G*Power software (version 3.1.9). The parameters used for the calculation were alpha level of 0.05, statistical power of 80% and an expected effect size of f = 0.4. A total of 72 samples were divided into three groups, each containing 24 samples (Figure 1). The first group (Fast-Fast) used a light-body fast-set impression material in combination with a regular-body fast-set material. The second group (Fast-Normal) utilized a light-body fast-set impression material, along with a regular-body normal-set material. Finally, the third group (Normal-Fast) used a light-body normal-set impression material, together with regular-body fast-set material. All impressions were collected from a Nissin typodont using a standardized preparation on two teeth: Molar #16 and premolar #24. All impressions were taken and evaluated by two calibrated clinicians and were created using a conventional method, with stock trays and tray adhesives applied. The impression materials were mixed using a manual dispensing gun and light-body impression materials were carefully injected around the prepared tooth. The trays were then filled with the same amount of regular-body material and topped off with light-body material. Impressions were visually assessed for

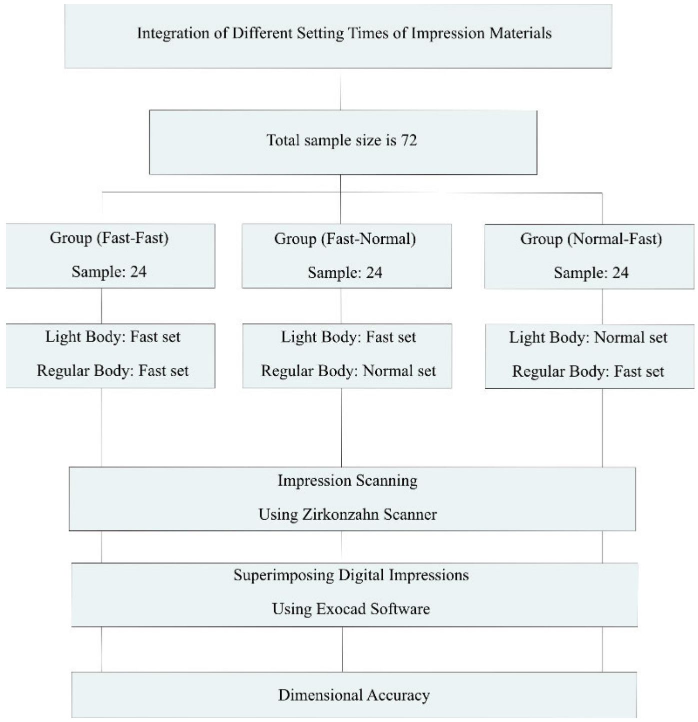

Figure 1: Experimental workflow showing the distribution of dental impression samples

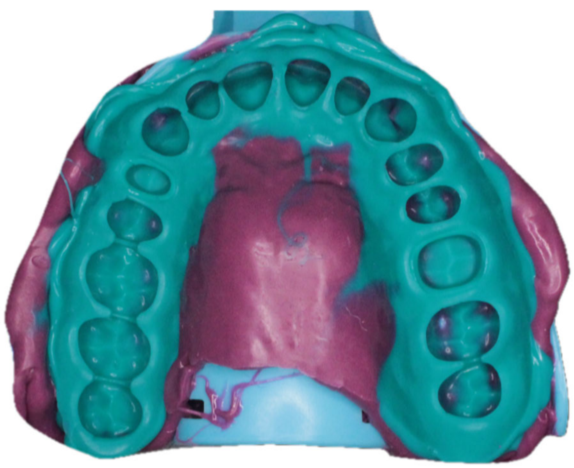

Figure 2: Maxillary impression using a two-step technique with light and regular body silicone materials

Figure 3: Reference cast of Nissin typodont used as a control for dimensional accuracy comparison

abutment clarity and the presence of voids or tears. All samples included in the study had a clear finish line without any defects, ensuring a usable impression (Figure 2). After visual assessment of the impressions, they were digitized using a Zirkonzahn scanner and primary Nissin typodont was chosen as the reference digital cast (Figure 3). Digital impressions were then superimposed to assess the accuracy of the impressions. Digital impressions were aligned and overlayed to impressions of the reference cast and alignment was performed using reference points or landmarks on the casts to ensure precise positioning. After superimposing the digital impressions, the overlapping areas were measured using digital calipers and specialized software tools in Exocad. We measured six specific parameters related to the height and width of dental impressions in millimeters (Figure 4). For height, we evaluated mesial, distal, buccal and palatal measurements. Furthermore, we assessed the mesiodistal and buccopalatal dimensions.

Statistical Analysis

Statistical analysis, particularly a one-way analysis of variance (ANOVA), was performed to determine any significant differences across multiple groups that represent different combinations of setting time impression materials. Prior to conducting ANOVA, the distribution of variables within each group was assessed using tests of normality (Kolmogorov–Smirnov and Shapiro–Wilk tests). The data exhibited normal distribution ($p>0.05$) for all groups,

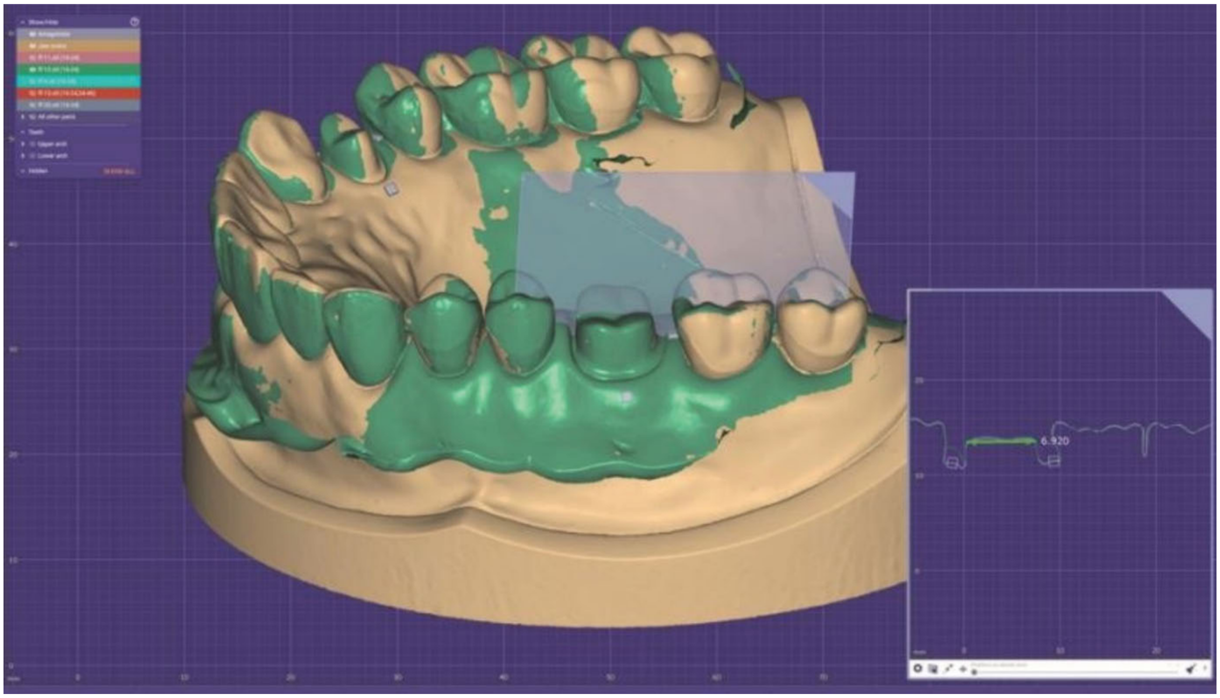

Figure 4: Digital superimposition and measurement of impression scan using Exocad software

Table 1: Elastomers' impression materials properties

Material	Advantages	Key properties
Polyvinyl Siloxane (PVS)	• High dimensional stability • Excellent elastic recovery • High tear strength • Minimal polymerization shrinkage	• Hydrophobic • Available in multiple viscosities • Long working/setting time (regular set)
Polyether (PE)	• Good dimensional accuracy • Hydrophilic	• Rigid • Low tear strength • Difficult removal from undercuts • Possible allergic reactions
Polyvinyl Ether Silicone (PVES)	• Combines hydrophilicity and elasticity • High flexibility and tensile strength • Suitable for undercuts	• Hybrid material (PVS + PE) • Newer material with limited clinical data • Balanced flow and elastic recovery

confirming the appropriateness of parametric testing. Tamhane's test was selected because it is a conservative method that does not assume equal variances between groups, making it suitable in cases where the assumption of homogeneity of variances may be violated. The purpose of these statistical assessments was to determine whether there were any statistically significant differences in the measured parameters, which in this case was the dimensional accuracy of the impressions between the control and experimental groups.

RESULTS

This study compared three groups of setting times of impression materials compared to the primary Nissin typodont as the reference digital cast. ANOVA revealed statistically significant differences between the groups for three variables: buccal ($p = 0.0002$), mesiodistal ($p = 0.0002$) and buccopalatal ($p = 0.006$) (Table 1). For buccal difference, the mean and 95% Confidence Interval (CI) were as follows: Fast-Fast group (0.0128, 95% CI:-0.0143, 0.0399), Fast-Normal group (0.0860, 95% CI: 0.0552, 0.1167) and Normal-Fast group (0.0791, 95% CI: 0.0560, 0.1022). For mesiodistal difference, the means and 95% CIs were as follows: Fast-Fast group (-0.0095, 95% CI:-0.0423, 0.0233), Fast-Normal group (0.0585, 95% CI: 0.0385, 0.0785) and Normal-Fast group (0.0546, 95% CI: 0.0323, 0.0769). For buccopalatal difference, the means and 95% CIs were as follows: Fast-Fast group (0.0618, 95% CI:-0.0009, 0.1246), Fast-Normal group (0.1693, 95% CI: 0.1311, 0.2075) and Normal-Fast group (0.1156, 95% CI: 0.0793, 0.1518) (Table 3). There were no statistically significant differences among the groups in terms of mesial ($p = 0.638$), distal ($p = 0.597$) or palatal differences ($p = 0.785$) (Table 2). This implies that the choice of impression material affects specific dimensional differences in dental impressions. Post-hoc assessments (Tamhane) revealed that the Fast-Normal group exhibited significantly different mean values compared to those of both the Fast-Fast and Normal-Fast groups (Table 4). The

Table 2: One-way ANOVA results comparing dimensional differences between impression groups for six measurement parameters

Parameters		Sum of Squares	df	Mean Square	F	Sig.
Meisal Difference	Between Groups	0.024	2	0.012	0.453	0.638
	Within Groups	1.798	69	0.026		
	Total	1.822	71			
Distal Difference	Between Groups	0.003	2	0.001	0.519	0.597
	Within Groups	0.172	69	0.002		
	Total	0.174	71			
Buccal Difference	Between Groups	0.078	2	0.039	9.48	<0.001
	Within Groups	0.285	69	0.004		
	Total	0.364	71			
Palatal Difference	Between Groups	0.003	2	0.002	0.243	0.785
	Within Groups	0.484	69	0.007		
	Total	0.487	71			
Mesio Distal Difference	Between Groups	0.07	2	0.035	9.485	<0.001
	Within Groups	0.254	69	0.004		
	Total	0.324	71			
Bucco Plalatal Difference	Between Groups	0.139	2	0.069	5.523	0.006
	Within Groups	0.866	69	0.013		
	Total	1.004	71			

Table 3: Descriptive Statistics: Mean (SD), Standard Error and 95% CI for Setting Time Combinations

Parameters			N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
							Lower Bound
Meisal Difference	Fast-Fast		24	0.0059	0.19946	0.04071	-0.0783
	Fast-Normal		24	0.0412	0.08572	0.0175	0.005
	Normal-Fast		24	0.0002	0.1762	0.03597	-0.0742
	Total		72	0.0158	0.16018	0.01888	-0.0219
	Model	Fixed Effects			0.16143	0.01902	-0.0222
		Random Effects				0.01902[a]	-0.0661[a]
Distal Difference	Fast-Fast		24	0.0554	0.05513	0.01125	0.0321
	Fast-Normal		24	0.0672	0.0516	0.01053	0.0455
	Normal-Fast		24	0.0538	0.0419	0.00855	0.0361
	Total		72	0.0588	0.04952	0.00584	0.0472
	Model	Fixed Effects			0.04986	0.00588	0.0471
		Random Effects				0.00588[a]	0.0336[a]
Buccal Difference	Fast-Fast		24	0.0128	0.06416	0.0131	-0.0143
	Fast-Normal		24	0.086	0.07281	0.01486	0.0552
	Normal-Fast		24	0.0791	0.05466	0.01116	0.056
	Total		72	0.0593	0.07158	0.00844	0.0425
	Model	Fixed Effects			0.06431	0.00758	0.0442
		Random Effects				0.02333	-0.0411
Palatal Difference	Fast-Fast		24	0.1089	0.11752	0.02399	0.0593
	Fast-Normal		24	0.1001	0.05323	0.01087	0.0776
	Normal-Fast		24	0.117	0.06628	0.01353	0.089
	Total		72	0.1087	0.08284	0.00976	0.0892
	Model	Fixed Effects			0.08374	0.00987	0.089
		Random Effects				0.00987[a]	0.0662[a]
Mesio Distal Difference	Fast-Fast		24	-0.0095	0.07768	0.01586	-0.0423
	Fast-Normal		24	0.0585	0.04738	0.00967	0.0385
	Normal-Fast		24	0.0546	0.05278	0.01077	0.0323
	Total		72	0.0345	0.0676	0.00797	0.0186
	Model	Fixed Effects			0.06073	0.00716	0.0203
		Random Effects				0.02204	-0.0603
Bucco Plalatal Difference	Fast-Fast		24	0.0618	0.14858	0.03033	-0.0009
	Fast-Normal		24	0.1693	0.09047	0.01847	0.1311
	Normal-Fast		24	0.1156	0.08586	0.01753	0.0793
	Total		72	0.1156	0.11892	0.01402	0.0876
	Model	Fixed Effects			0.112	0.0132	0.0892
		Random Effects				0.03102	-0.0179

Fast-Normal group generally had larger mean values for buccal, mesiodistal and buccopalatal differences, suggesting that combining fast-set and normal-set materials resulted in greater dimensional differences compared to those with the other groups. The Kolmogorov-Smirnov and Shapiro-Wilk tests revealed some deviations from normality for variables such as mesial, palatal, mesiodistal and buccopalatal differences between the groups (Table 5).

Table 4: Multiple Comparison Analysis: Tamhane's Test for Setting Time Combinations

Dependent Variable		(I) Impression Material	(J) Impression Material	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Meisal Difference	Tamhane	Fast-Fast	Fast-Normal	-0.03525	0.04431	0.817	-0.147	0.0765
Distal Difference			Normal-Fast	0.00567	0.05433	0.999	-0.129	0.1404
		Fast-Normal	Fast-Fast	0.03525	0.04431	0.817	-0.0765	0.147
			Normal-Fast	0.04092	0.04	0.677	-0.0596	0.1415
		Normal-Fast	Fast-Fast	-0.00567	0.05433	0.999	-0.1404	0.129
			Fast-Normal	-0.04092	0.04	0.677	-0.1415	0.0596
	Tamhane	Fast-Fast	Fast-Normal	-0.01183	0.01541	0.831	-0.05	0.0264
			Normal-Fast	0.00158	0.01414	0.999	-0.0335	0.0367
Buccal Difference		Fast-Normal	Fast-Fast	0.01183	0.01541	0.831	-0.0264	0.05
			Normal-Fast	0.01342	0.01357	0.697	-0.0203	0.0471
		Normal-Fast	Fast-Fast	-0.00158	0.01414	0.999	-0.0367	0.0335
			Fast-Normal	-0.01342	0.01357	0.697	-0.0471	0.0203
	Tamhane	Fast-Fast	Fast-Normal	-0.07317*	0.01981	0.002	-0.1223	-0.0241
			Normal-Fast	-0.06633*	0.01721	0.001	-0.109	-0.0237
		Fast-Normal	Fast-Fast	0.07317*	0.01981	0.002	0.0241	0.1223
			Normal-Fast	0.00683	0.01858	0.977	-0.0394	0.053
		Normal-Fast	Fast-Fast	0.06633*	0.01721	0.001	0.0237	0.109
Palatal Difference			Fast-Normal	-0.00683	0.01858	0.977	-0.053	0.0394
	Tamhane	Fast-Fast	Fast-Normal	0.00875	0.02633	0.983	-0.0576	0.0751
			Normal-Fast	-0.00808	0.02754	0.988	-0.077	0.0608
		Fast-Normal	Fast-Fast	-0.00875	0.02633	0.983	-0.0751	0.0576
			Normal-Fast	-0.01683	0.01735	0.709	-0.0599	0.0262
		Normal-Fast	Fast-Fast	0.00808	0.02754	0.988	-0.0608	0.077
			Fast-Normal	0.01683	0.01735	0.709	-0.0262	0.0599
	Tamhane	Fast-Fast	Fast-Normal	-0.06796*	0.01857	0.002	-0.1143	-0.0216
Mesio Distal Difference			Normal-Fast	-0.06412*	0.01917	0.005	-0.1119	-0.0164
		Fast-Normal	Fast-Fast	0.06796*	0.01857	0.002	0.0216	0.1143
			Normal-Fast	0.00383	0.01448	0.991	-0.0321	0.0397
		Normal-Fast	Fast-Fast	0.06412*	0.01917	0.005	0.0164	0.1119
			Fast-Normal	-0.00383	0.01448	0.991	-0.0397	0.0321
	Tamhane	Fast-Fast	Fast-Normal	-0.10746*	0.03551	0.013	-0.1961	-0.0188
			Normal-Fast	-0.05375	0.03503	0.349	-0.1414	0.0339
		Fast-Normal	Fast-Fast	0.10746*	0.03551	0.013	0.0188	0.1961
Bucco Plalatal Difference			Normal-Fast	0.05371	0.02546	0.116	-0.0094	0.1168
		Normal-Fast	Fast-Fast	0.05375	0.03503	0.349	-0.0339	0.1414
			Fast-Normal	-0.05371	0.02546	0.116	-0.1168	0.0094

*The mean difference is significant at the 0.05 level

Table 5: Shapiro-Wilk and Kolmogorov-Smirnov Normality Tests for Different Combinations of the Setting Time of the Impression Material

	Impression Material	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
MeisalDifference	Fast-Fast	0.367	24	<0.001	0.607	24	<0.001
	Fast-Normal	0.245	24	<0.001	0.876	24	0.007
	Normal-Fast	0.393	24	<0.001	0.505	24	<0.001
DistalDifference	Fast-Fast	0.188	24	0.028	0.851	24	0.002
	Fast-Normal	0.111	24	0.200*	0.962	24	0.479
	Normal-Fast	0.118	24	0.200*	0.933	24	0.111
BuccalDifference	Fast-Fast	0.142	24	0.200*	0.962	24	0.479
	Fast-Normal	0.103	24	0.200*	0.947	24	0.23
	Normal-Fast	0.177	24	0.051	0.952	24	0.294
PalatalDifference	Fast-Fast	0.19	24	0.025	0.751	24	<0.001
	Fast-Normal	0.111	24	0.200*	0.961	24	0.459
	Normal-Fast	0.089	24	0.200*	0.973	24	0.751
MesioDistalDifference	Fast-Fast	0.284	24	<0.001	0.614	24	<0.001
	Fast-Normal	0.154	24	0.147	0.96	24	0.43
	Normal-Fast	0.1	24	0.200*	0.962	24	0.485
BuccoPlalatalDifference	Fast-Fast	0.317	24	<0.001	0.639	24	<0.001
	Fast-Normal	0.15	24	0.173	0.959	24	0.41
	Normal-Fast	0.16	24	0.114	0.934	24	0.123

*This is a lower bound of the true significance, aLilliefors Significance Correction

DISCUSSION

This study aimed to establish evidence-based recommendations to enhance the reliability of dental impression techniques by evaluating the effects of combining different setting times of impression materials on accuracy and reproducibility. Conducted in a controlled laboratory setting, it eliminated clinical variations to ensure precise results. Findings indicate that combining impression materials with different setting times significantly influenced the buccal, mesiodistal and buccopalatal dimensions of dental impressions, while mesial, distal and palatal differences showed no statistically significant variations. These results led to the rejection of the null hypothesis, suggesting that material selection impacts only specific dimensional aspects. While theoretically beneficial in certain cases, combining different setting times requires proper handling, technique and material compatibility, which manufacturers generally do not recommend due to potential risks to accuracy. Despite limited previous research on this approach, further investigations are needed to assess its feasibility. Traditionally, clinicians have avoided mismatched setting times due to concerns about distortion. However, this study suggests that such combinations may be viable, providing flexibility in material selection without compromising accuracy. This could help reduce material waste and costs associated with cartridges.

Despite these promising findings, the study's controlled laboratory conditions present limitations, such as the exclusion of biological factors like soft tissues and saliva. Future clinical research is necessary to validate these results and assess potential variations introduced by patient-related or operator-dependent factors. Overall, this study provides valuable insights into impression-material combinations and their clinical relevance.

CONCLUSIONS

This study investigated the effect of impression materials with different setting times on various dimensional aspects of dental impressions. The key findings clearly demonstrate that the setting time has a significant influence on certain dimensional measurements. Our findings have important clinical implications for dental professionals as the choice of impression material and setting time can directly influence the dimensional accuracy of the final impression. As such, careful consideration should be given to material selection, particularly when the precision in specific dimensions is critical for optimal fit and function. Overall, this study highlights the importance of understanding the impact of impression material properties, such as setting time, on the dimensional accuracy of dental impressions. Considering these factors, dental professionals can make informed decisions to improve the quality and fit of prosthetic restorations and ultimately enhance patient outcomes.

Limitations

- This *in vitro* study excludes biological factors such as soft tissues and saliva
- The study is performed in a controlled laboratory environment
- This research specifically investigated a particular type of impression material, which may restrict the generalizability of the findings
- This study focused on linear measurements and did not assess surface detail reproduction

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

The research proposal was approved by the regional research and ethics committee of King Abdulaziz University with an Ethical Approval number (167-11-23).

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