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Rheological properties of elastomeric impression materials for selective pressure impression technique

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ABSTRACT

Purpose: The selective impression technique is recommended for removable prosthodontics. However, the viscoelastic rheological properties of impression materials, particularly the time-dependent viscoelastic changes in impression material immediately after tray seating, are unknown. The objective of this study is to clarify the viscoelastic rheological properties of impression materials by focusing on tray seating.
Methods: In this study, eight types of polyvinylsiloxane (PVS), two types of polyether, and two types of alginate impression materials were used. The storage modulus (G'; degree of stiffness) and loss tangent ($\tan\delta$; degree of hardening) were determined as functions of time from 0 to 360 s, commencing immediately after the completion of mixing, using a stress control-type rheometer. Thus, G' and $\tan\delta$ at 0 s and 20 s were compared.
Results: Stiffness was found to be widely distributed (4.49–0.26 $\times 10^4$ Pa) among PVS-types, even immediately after mixing the impression material. There was also variation among polyethers (1.55–0.5 $\times 10^4$ Pa) and among alginates (0.64–0.21 $\times 10^4$ Pa). The hardening of all impression materials progresses beyond 20 s after the completion of mixing.
Conclusions: The G' values varied with each impression material, even immediately after mixing, and the accurate impression-taking time was determined from the results of $\tan\delta$. These results provide unique insight into the selective impression technique.

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Table 1 – Impression materials.

Constituent	Material	Batch No.	Manufacturer	Manufacturer's instruction	
				Operating time (from start of mixing)	Operating + tray holding time
Polyvinylsiloxane	EXADENTURE (ED)	1209041	GC, Tokyo, Japan	2.5 (min)	5.5 (min)
	EXAMIXFINE INJECTION TYPE (EM)	1207202	GC, Tokyo, Japan	3	6
	EXAHIFLEX INJECTION TYPE (EH)	1207061	GC, Tokyo, Japan	2	5
	SILDE FIT REGULAR&DENTURE TYPE (SI)	121101	Shofu, Kyoto, Japan	2	6
	Aquasil Ultra XLV (AQ)	120702	Dentsply-Sankin, Tokyo, Japan	2.5	5
	Imprint3 Light Body (IP)	478530	3M ESPE, Neuss, Germany	2	5.5
	Genie Extra Light Body (GE)	114110826	MORITA, Osaka, Japan	2.5	4.5
	AFFINIS PRECIOUS light body (AF)	D60246	YOSHIDA, Tokyo, Japan	1	3
Polyether	Impregum Soft Medium Body (IG)	483627	3M ESPE, Neuss, Germany	2.5	6
	FUSION II EXTRA WASH TYPE (FU)	1208201	GC, Tokyo, Japan	2	5
Alginate	AROMA FINE PLUS NORMAL SET (AR)	1311191	GC. Tokyo, Japan	2.17	4.17
	ALGIACE Z (AL)	481–883	Dentsply-Sankin, Tokyo, Japan	2	4

1. Introduction

Impression methods for removable prosthodontics can be roughly classified into four techniques (mucocompressive, mucostatic, selective-pressure and functional) based on the ideas presented over the years in relation to applied pressure [1–4]. Among these, the selective impression technique has been widely used based on a histologic understanding of the supporting tissues that are anatomically favorable for withstanding pressure [5–8].

The aim of the impression technique is to control the impression pressure by seeking and providing support in the stress-bearing areas where functional stresses can be tolerated so that as little pressure as possible is applied to the more fragile sections [9]. To achieve this, tray design [10–13], seating velocity of the impression tray [12,14], and viscoelasticity of impression materials must be considered [15–20]. With regard to tray design, Komiyama et al. [13] noted that when making an impression of an edentulous maxillary arch using the selective pressure technique, optimal pressure can be obtained using a tray with escape holes of 1.0 mm or larger, or a 1.40-mm-thick wax base plate as a spacer. For seating velocity of the impression tray, Hyde et al. [14] showed that the seating velocity has a significant effect on peak pressure generated by the impression, and implied that the seating velocity of the impression tray should be considered in clinical settings. For the viscosity of impression materials, McCabe et al. [16] showed, by rheological testing of elastomeric impression materials and that the time-dependent viscoelastic rheological properties differ between impression materials. Berg et al. [17] showed that the surrounding temperature significantly affects the setting time and the magnitude of the storage modulus (solid-like behavior). However, it was also reported that the tray design has less to do with pressure and that the actual impression material is the most influential [11,18]. Tray modification had little effect on the amount of pressure produced. Thus, when we consider the pressure during impression taking for dentures, the viscoelastic rheological properties of impression material and the time immediately after seating a tray with the impression material into the mouth (the initial stage of seating), are considered to be most important [14,15]; however, there have been few reports on time-dependent changes due to differences in impression materials.

At present, the most widely used elastomers in dental practice are polyvinylsiloxanes and polyethers [21]. Alginates are not recommended for secondary impressions for complete dentures [22]. In recent years, however, it has been reported that a simplified protocol with a stock tray and alginate results in comparable patient perceptions of treatment outcomes as compared with traditional protocols [23]. Accordingly, the objective of this study is to investigate the detailed time-dependent rheological changes in the viscoelasticity of various impression materials, which can be used for removable dentures. In particular, we aimed to clarify the viscoelastic rheological properties of impression materials in settings similar to actual clinical settings by focusing on the time period of tray seating. Thus, the selective impression technique in clinical prosthodontics has become more certain.

2. Materials and methods

In this study, eight types of polyvinylsiloxane (PVS) elastomer, two types of polyether elastomer and two types of alginate impression material, which are used in impression taking for dentures and are presently commercially available, were used. Abbreviations for the respective impression materials are shown in Table 1. Because FU is a hybrid of PVS and polyether, it was classified as a polyether. The manufacturer's instructions were followed for mixing of each impression material.

Mixing was carried out at room temperature (23 ± 1 °C) and a humidity of 50 ± 5%, and the dynamic viscoelasticity of each