The Influence of Custom Tray Spacers on Impression Pressure Induced by Different Universal Polyvinyl Siloxane Impression Materials: An In Vitro Study

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Abstract

Aims: A muco-static impression is considered the ideal goal for edentulous impression and pressure control against the membrane relates to the impression materials and custom tray spacer. This study aimed to determine the differences in impression pressure with four commonly used edentulous impression material, polyvinyl siloxane (PVS). The study also investigated the influence of custom tray spacer thickness.

Methods: Shore-A hardness, consistency, elasticity, viscosity coefficient, and viscoelastic modulus were measured for the EXAMIXFINE injection (EFI) and regular (EFR), and EXAHIFLEX injection (EHI) and regular (EHR). Flat disks (72mm in diameter; simulated as edentulous ridge) and an impression tray were prepared. Two pressure sensors (PS-1KD; Kyowa Electronic Instruments Corp., Tokyo, Japan) were embedded into the flat disk as simulated as edentulous ridge at two measuring points (point-0: center of the disk and point-A: 18mm from the center). Three types of the spacers 0.3mm (03-tray), 0.6mm (06-tray) and with 0.9mm (09-tray) were prepared to simulate the custom trays.

Results: EFI and EFR showed significantly high shore-A hardness than those of the EHI and EHR. Consistency was significantly high with the injections. EHI and 06-trays showed minimum pressure at point-0 and point-A. With the 09-tray, all PVS materials showed no significant differences between the two points with almost non-pressure values.

Conclusions: Clinicians are recommended to design at least 06-trays for the muco-static impression with the EHI with minimizing the pressure when pouring the dental stone to the impression. With the 09-trays, the pressure after polymerization was similar, and

equilibrium was established between the two measurement points.

Introduction

The soft tissue covering the residual ridge of the edentulous ridge has its unique character to resist various occlusal force transmitted through removable prostheses. Notably, with a conventional complete denture, the membrane underneath the denture acts as a functional force bearing system, when the denture is in an occluding phase and unilateral occlusal balance phase (1-4). It is also considered that chewing rate and reactive hyperemia have an influence on blood flow in denture-supporting mucosa during simulated chewing (5). The denture supporting soft tissue is also important for denture retention as it maintains a negative pressure that occurred in between the membrane and denture basal surface (6) .

The edentulous ridge membrane is unique in terms of its thickness, variability and the functional force should be arranged and distributed according to the tissue membrane thickness (7). Considering these membrane characteristics, conventional complete denture fabrication, especially during the impression taking, the pressure control of the alveolar ridge membrane is crucial. In other words, accurate impression taking is critical for controlling the pressure of the membrane, both during function and at rest. The impression technique usually uses selective-pressure impression (8) or minimal pressure for denture bearing tissues, muco-static impression (9). The pressure control against the membrane is dependent on the impression materials and custom tray spacer (10-15). Therefore, determining the pressure induced by the impression materials during the final impression according to various spacer thicknesses of the custom tray is important to guide the selection of the impression materials by clinicians.

Various in vitro studies have examined impression materials and the spacer design of custom trays for selective impression and minimal impression pressure techniques (13, 16-18). Some research concluded that tray modification was not important in changing the amount of pressure, both with the maxilla (18) and mandible (17). However, these studies have not changed various tray spacers, and few studies had simultaneously monitored the impression pressure at the different sites on the denture bearing tissues. However, these studies have not changed various tray spacers, and few studies had simultaneously monitored the impression pressure at the different sites on the denture bearing tissues. Thus, this in vitro study was designed to determine the differences of conventional edentulous impression material, polyvinyl siloxane (PVS) pressure at two points on the denture bearing area. It also investigated the influence of various custom tray with different spacer thickness. This study aimed to provide basic guidelines for the selection of optimum impression materials and tray spacer settings to minimize impression pressure for denture bearing tissues in a clinical setting in a more objective manner than empirical experience (19).

The properties of four PVS impression materials used for the final impression (20) were characterized and the impression pressures recorded by two pressure sensors embedded into flat disks were determined to guide edentulous tray design and elucidate the effect of spacers on impression pressure. The null hypotheses were that no significant differences would be observed 1) between the properties of the four PVS impression materials and 2) between the impression pressures measured with different tray spacers.

Materials and Methods

1. Properties of the PVS impression materials

1.1 PVS and outcomes

Table 1 shows the four test materials: the universal PVS impression materials: EXAMIXFINE injection (EFI) and regular type (EFR), EXAHIFLEX injection (EHI) and regular type (EHR) (GC, Tokyo Japan). Shore-A hardness, consistency, elasticity, viscosity coefficient, and viscoelastic modulus were the measured outcomes.

1.2 Measurements

Shore-A hardness was measured using a durometer (WR-202NA, Nishi Tokyo seimitsu, Tokyo, Japan) as prescribed by the JIS standard. Consistency was measured by using two glass plates prescribed by the JIS standard. Elasticity, viscosity coefficients, and viscoelastic modulus were measured by portable wireless viscoelasticity system (E-100HB, WaveCyber, Saitama, Japan).

1.3 Analysis

The properties of the PVS impression materials were compared among injection and regular types using analysis of variance (ANOVA) and post-hoc test (Tukey's test) with 5% as level of significance.

2. Simulation model

2.1 Simulated tray

Flat disks (72mm in diameter; simulated as edentulous ridge) and an impression tray were prepared for the experiment (21). Two pressure sensors (PS-1KD; Kyowa Electronic Instruments Corp., Tokyo, Japan) were embedded into the flat disk as simulated as edentulous ridge to measure the impression pressure at two measuring points (point-0: center of the disk and point-A: 18mm from the center). Three types of the spacers were prepared for the disk to simulate the custom trays, 0.3mm (03-tray), 0.6mm (06-tray) and with 0.9mm (09-tray; Fig. 1). The ridge simulating disks and impression trays were fabricated with auto-polymerizing acrylic resin (Ostron 100, GC Corp., Tokyo, Japan).

2.2 Measurement environment

The measurement environment was set to a temperature of 23±2℃ and 50±5% of relative humidity. The disks were attached to the rheometer (CR- 200D; SUN Scientific Co. Ltd, Tokyo, Japan) with loading force conditioned at 4,800gf and pressure speed of 120mm/minute(22).

2.3 Compression and measurement

The measurement commenced immediately before the pressing during the polymerization of the materials (4min of sampling time at 5Hz). The data corresponding to point-0 and point-A were calculated using a sensor interface (PCD-300A, Kyowa Electronic Instruments Corp., Tokyo, Japan) and simultaneously recorded on a personal computer (Fig. 2). The data were obtained at 4min after polymerization. The measurements were repeated seven times for each respective tray and material.

2.4 Analysis

The effect of the spacer on pressure induced by each impression was compared at point-0 and point-A by ANOVA followed by post hoc tests (Tukey’s test). Equalization of pressure between point-0 and point-A were assessed within the same impression materials. Significant level was set to 5% for both analyses.

All analyses were performed by using a computer software package (SPSS 11.0 for

Windows; SPSS, Chicago, Ill).

Results

1. Properties of study impression materials

1.1 Shore-A hardness

The highest shore-A hardness was observed for the EFR samples (39.9±0.9) and the lowest was the EHI samples (21.0±1.1). EHI and EHR showed significantly lower shore-A hardness than those of the EFI and EFR (Fig. 3).

1.2 Consistency

Consistency was the highest for the EFI group (45.4±0mm), whereas EHR exhibited the lowest values (36.57±1.7mm). The consistency was significantly higher for the injections than the regular PVS material samples; EFI>EFR and EHR, and EHI>EFR and EHR (Fig. 4).

1.3 Elasticity

Elasticity was highest for the EFR samples (3651.0±87.8kPa) and lowest for the EHI samples (2406.0±12.5kPa). Significant differences were observed among the materials (Fig. 5).

1.4 Viscosity coefficient

The highest viscosity coefficient was observed for EHR (852.1±82.2Pa-s), whereas EHI showed the smallest coefficient (447.1±31.8Pa-s). Significant differences were observed among the materials (*p*<0.05), except for between EFR and EHI (Fig. 6).

1.5 Viscoelastic modulus

The highest viscoelastic modulus was observed for EHR (44.3±0.8%) and the lowest for EFI (37.3±1.0%). Significant differences were observed among the materials (*p*<0.05), except for between EFR and EHI (Fig. 7).

2. Impression pressures

2.1 Pressure induced at point-0 (Table 2)

All materials showed significantly lower impression pressures with the 09-tray compared to those of the 03-tray and 06-tray, except EHI that showed no significant differences between the 06-tray and 09-tray. For the pressures obtained using the 03-tray and 06-tray, only EFR showed no significant difference and the other materials showed significantly lower impression pressures with the 06-tray.

2.2 Pressure induced at point-A (Table 3)

All materials showed significantly lower impression pressures with the 09-tray compared to those of the 03-tray and 06-tray, except EHI showed no significant difference between the 06-tray and 09-tray. For the 03-tray and 06-tray, all materials showed significantly lower impression pressures with the 09-tray.

2.3 The pressure between point-0 and A (Fig. 8 a, b, c)

Figure 8a shows the difference between the pressures recorded at point-0 and point-A of the 03-tray. All PVS materials showed significantly lower pressures at point-A. Figure 8b shows the difference between the pressures recorded at point-0 and point-A of the 06-tray. Only EHI showed no significant difference between the two point with the lowest and close to a non-pressure value. Figure 8c shows the difference between the pressures recorded at point-0 and point-A of the 09-tray. All PVS materials showed no significant differences between the two points with almost non-pressure values.

Discussion

Impression taking of the edentulous ridge is essential for recording the ridge surface and transferring the denture bearing area to the working cast. Accurate impressions and cast strongly influence the final quality of the denture. The study aimed to clarify the properties of four PVS materials commonly used for the final impression of an edentulous ridge of the complete dentures. The study also investigated the effect of tray spacer and tray position on the impression pressures 4min after the polymerization. In this manner, we aimed to explore the application of edentulous tray design for controlling impression pressure. The physical properties may differ among the four materials with the hardness and elasticity. Also, the difference in tray space is supposed to change the impression pressure. Although it will be impossible to solve all the impression properties of materials and methods, the studied material is considered to hold a common physical property; thus, the results are considered to be useful information to take impression objectively.

The shore-A hardness, consistency, elasticity, viscosity coefficient, and viscoelastic modules were assessed. The shore A hardness shows the character of hardness after the polymerization of the impression. Higher shore A hardness would indicate high resistance to deformation when dental plaster is poured to the impression. Among the test materials, EXAMIXFINE, both regular and injection, showed significantly higher values than the EXAHIFLEX regular and injection. The results indicate that EXAMIXFINE had less deformation when the dental stone was poured into fabricating the working cast than the EXAHIFLEX. Consistency is also essential to assess the flowability of the materials. A muco-static impression of the edentulous membrane is an important protocol (9, 23) and in consideration of this protocol, higher consistency, i.e. higher flowability, would be ideal for reflecting the muco-static to the impression and working cast. Among the test materials, injections showed significantly higher values than the regulars. These results indicate that the EFI could be the choice by holding higher followability before polymerization and higher hardness after the polymerization than the other test materials.

Viscosity coefficient could influence the design of forming adequate border moulding. Maruo et al. (19) investigated the preferred viscosity proposed by the prosthodontists of irreversible hydrocolloid used in the preliminary impression for edentulism. They concluded that "Prosthodontists could judge the preferred viscosity based on their clinical experiences. On the preliminary impression for edentulism, the preferred viscosity demonstrated in vitro using a polyurethane maxilla model was 1210Pa·s." In this study, the highest viscosity coefficient was EHR, which was lower than the result of Maruo et al. (19). For the final impression, the border moulding has been done before the wash impression; thus, lower viscosity than the irreversible hydrocolloid may be acceptable.

It is considered that the characters of these material properties can be adjusted via impression tray design by modifying the thickness of the impression space according to membrane resiliency (13-15, 24, 25). However, the difference in the pressure induced by the design of the tray, space thickness, and position in the tray (*i.e.* middle or external) remains ambiguous. In the edentulous model with a curved surface and various forms, the material flow is inconsistent, and the impression material thickness is uneven. Thus, as a basic model, we simulated the impression tray using the two disks, one simulating the edentulous ridge and the other simulating the tray and measured the respective pressure with three spacers. The measuring points were at the center of the disk and 18mm from the center. The values obtained at point-0, the center, were generally higher those measured at point-A, 18mm from the center, for all measurements with the 03-tray. When the spacer thickness was increased, the imbalanced pressure between point-0 and point-A equilibrated. It also indicated that minimized impression pressure could be gained from 06-trays with EHI. Although a significant difference between point-0 and point-A, EFI is almost close to EHI.

According to Odagiri *et al.* (7), mucosal displacement under pressure shows approximately constant displacement when exceeding pressurization of 30kPa. The results of this study showed that impression pressure after the polymerization was below 30kPa. Thus, the measurements were performed within the range of maximally pressurized mucosa, regardless of the impression material, spacer thickness, or distance from the pressure point.

In conclusion, clinicians are recommended to design at least 06-trays for the muco-static impression with the EHI with minimizing the pressure when pouring the dental stone to the impression. With the 09-trays, the pressure after polymerization was similar, and equilibrium was established between the two measurement points.

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Conflict of interest

The authors declare that there is no conflict of interest in this research.

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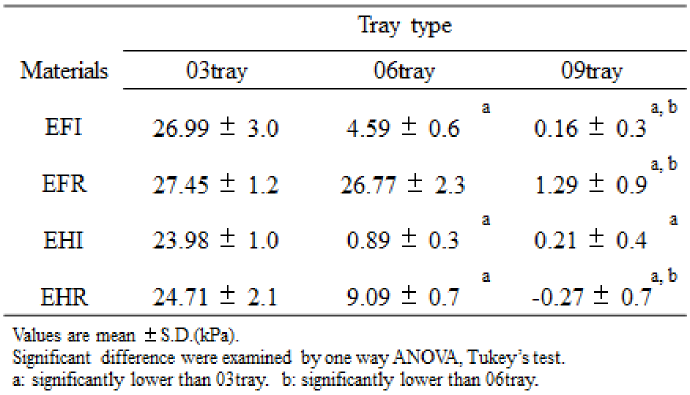
Tables and Figures

Table1 The test impression materials

Materials	Code	Lot no.
EXAMIXFINE (GC Corp., Tokyo)		
Injection	EFI	1108041
Regular	EFR	1108241
EXAHIFLEX (GC Corp., Tokyo)		
Injection	EHI	1104071
Regular	HER	1203221

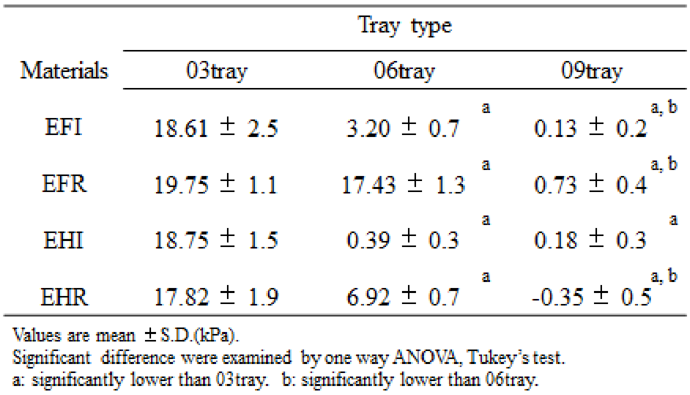
Table 2 Impression pressure value on Point-0



Materials	Tray type		
	03tray	06tray	09tray
EFI	26.99 ± 3.0	4.59 ± 0.6 ^{a}	0.16 ± 0.3 $^{a, b}$
EFR	27.45 ± 1.2	26.77 ± 2.3	1.29 ± 0.9 $^{a, b}$
EHI	23.98 ± 1.0	0.89 ± 0.3 ^{a}	0.21 ± 0.4 ^{a}
EHR	24.71 ± 2.1	9.09 ± 0.7 ^{a}	-0.27 ± 0.7 $^{a, b}$

Values are mean ± S.D.(kPa).
Significant difference were examined by one way ANOVA, Tukey's test.
a: significantly lower than 03tray. b: significantly lower than 06tray.

Table 3 Impression pressure value on Point-A



Materials	Tray type		
	03tray	06tray	09tray
EFI	18.61 ± 2.5	3.20 ± 0.7 ^{a}	0.13 ± 0.2 $^{a, b}$
EFR	19.75 ± 1.1	17.43 ± 1.3 ^{a}	0.73 ± 0.4 $^{a, b}$
EHI	18.75 ± 1.5	0.39 ± 0.3 ^{a}	0.18 ± 0.3 ^{a}
EHR	17.82 ± 1.9	6.92 ± 0.7 ^{a}	-0.35 ± 0.5 $^{a, b}$

Values are mean ± S.D.(kPa).
Significant difference were examined by one way ANOVA, Tukey's test.
a: significantly lower than 03tray. b: significantly lower than 06tray.

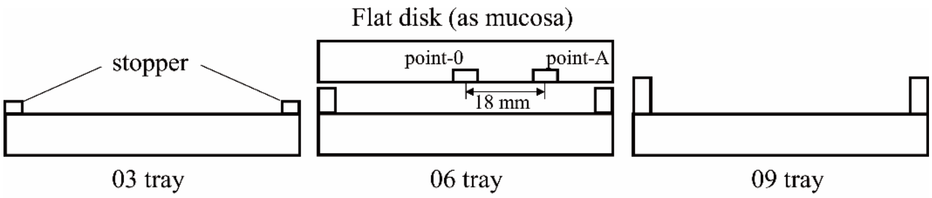


Fig. 1. The simulated flat disks as edentulous ridge and tray.
The pressure sensor embedded into cast at the center of the disk (point-0) and18 mm in position from point-0 (point-A). The tray was prepared with three thickness of spacer (0.3, 0.6, and 0.9 mm).

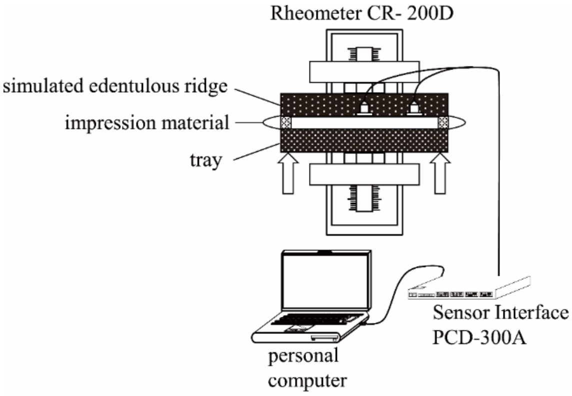


Fig. 2. Measuring system.
Flat disks were isotonically compressed under impression material between the two flat disks, by the rheometer. The sensor interface recorded the impression pressures and transfer to the personal computer.

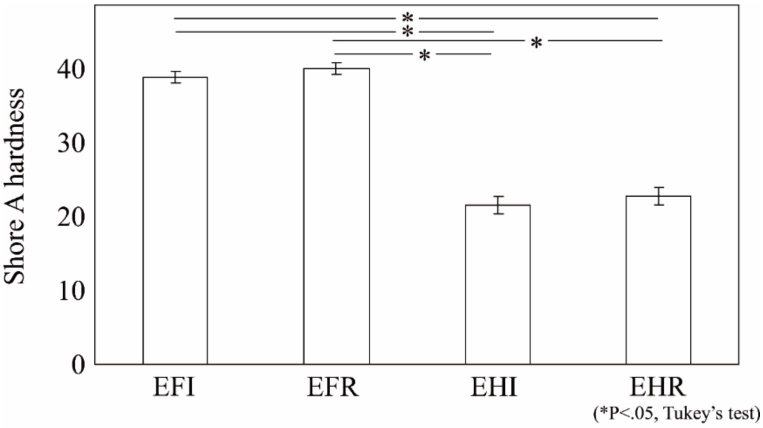
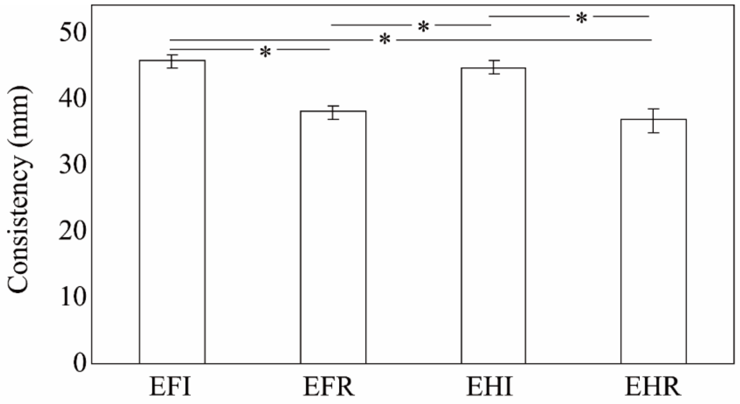
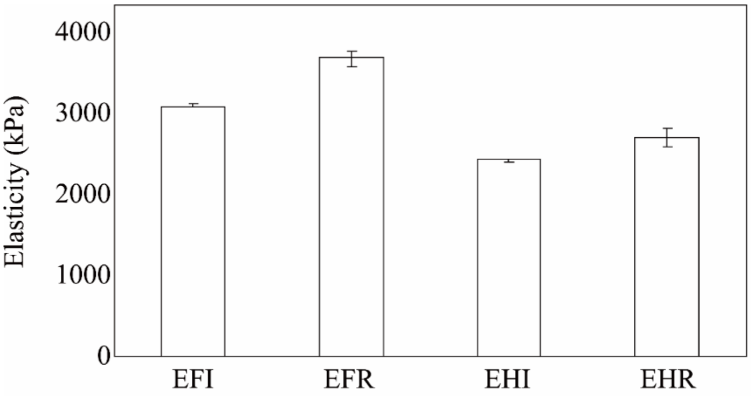


Fig. 3. Shore A hardness of respective impression materials



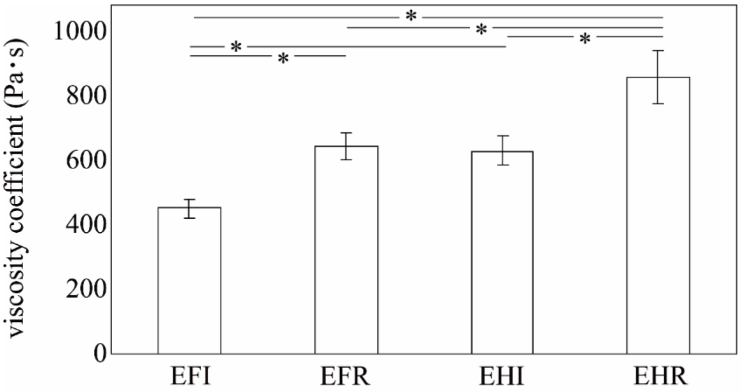
(*P<.05, Tukey's test)

Fig. 4. Consistency of respective impression materials.



A significant difference is in all the pairs.(*P<.05, Tukey's test)

Fig. 5. Elasticity of respective impression materials.



(*P<.05, Tukey's test)

Fig. 6. Viscosity coefficient of respective impression materials.

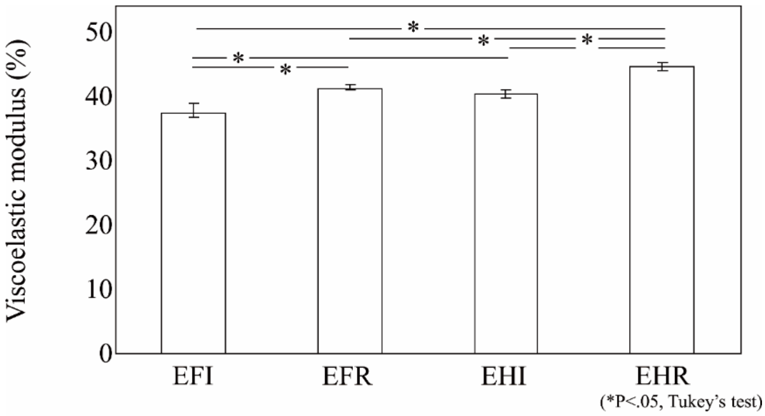


Fig. 7. Viscoelastic modules of respective impression materials.

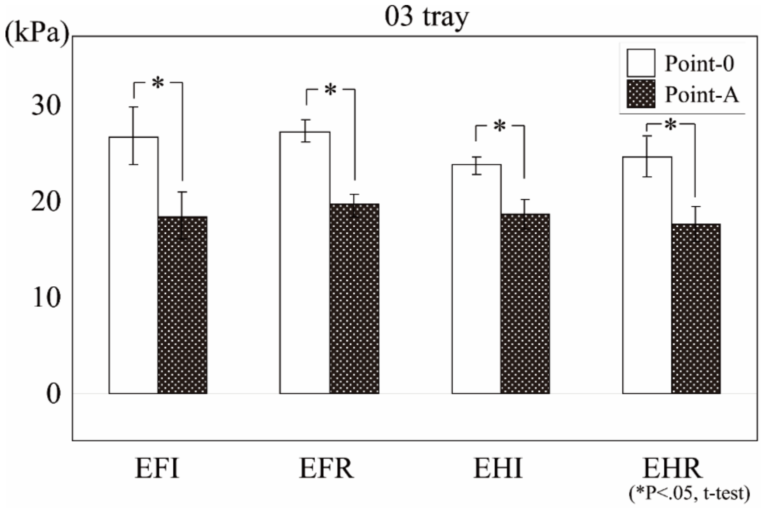


Fig. 8a: Impression pressures at two sensors in 03-tray.

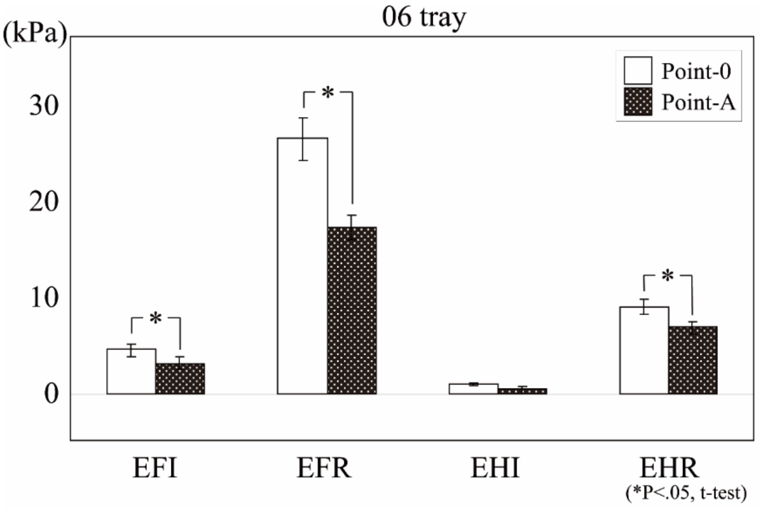


Fig. 8b: Impression pressures at two sensors in 06-tray.

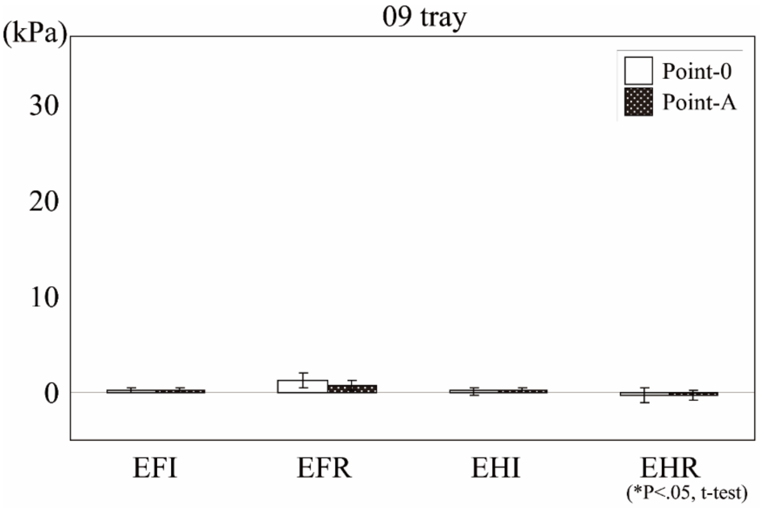


Fig. 8c: Impression pressures at two sensors in 09-tray.