Pressure Generated on a Simulated Mandibular Oral Analog by Impression Materials in Custom Trays of Different Design

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Purpose: The purpose was to measure the pressure exerted under a simulated mandibular edentulous impression at different locations using commonly used impression materials and four impression tray configurations.

Materials and Methods: This study was performed using an oral analog that simulated an edentulous mandibular arch. Three pressure transducers were embedded in the oral analog—one pressure transducer in the anterior ridge area, and the other two in the right and left buccal shelves. Four configurations of custom trays were fabricated: trays with no relief, with and without holes; and trays with relief, with and without holes. The impression materials tested were light body polysulfide, light body vinyl polysiloxane, medium body vinyl polysiloxane, and irreversible hydrocolloid. The custom tray and the oral analog were mounted using a reline jig, and a Satec universal testing machine was used to apply a constant pressure of 1 kg/cm^2 over a period of 5 minutes on the loaded custom tray. Eighty impressions for the 16 groups ($n = 5$) were made, and pressures were recorded every 10 seconds. Factorial ANOVA and Tukey Multiple Comparison Test were used to analyze the results ($p < 0.05$).

Results: A significant difference was found in the pressure produced using different impression materials. Irreversible hydrocolloid and medium body vinyl polysiloxane produced significantly higher pressure than light body polysulfide and light body vinyl polysiloxane impression materials. The presence of holes and/or relief significantly altered the magnitude of pressure produced by irreversible hydrocolloid and medium body vinyl polysiloxane but not light body polysulfide and light body vinyl polysiloxane.

Conclusion: All impression materials produced pressure during simulated mandibular edentulous impression making. For making mandibular edentulous impressions, low-viscosity impression materials—light body polysulfide and light body vinyl polysiloxane—are recommended. Tray modification was not important in changing the amount of pressure produced for the low-viscosity impression materials.

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THE DENTURE IMPRESSION is a critical step in determining the fit, esthetics, comfort, and efficiency of the denture. A complete denture impression is a negative registration of the entire denture bearing and border areas of the edentulous mouth. An accurate impression will help ensure the fabrication of a stable, retentive, and comfortable complete denture. This end result is enhanced by paying attention to the pressures produced during the final impression.[1,2]

The ideal impression is one embracing all the edentulous areas to be used by the denture and embodying a composite of the tissues at rest without any overcompression or displacement. Such an impression made with little or no pressure will ensure a positive adaptation of the denture.[3-6] Various materials and techniques have been considered for making complete denture impressions. These include selective pressure technique,[7,8] the functional impression technique,[9] and the mucostatic (nonpressure) impression technique.[10] The technique used for each patient should be selected based on the diagnosis of the basal seat and border tissues.

The proponents of selective pressure techniques recommend that the tissues of certain areas be displaced to gain specific advantages for retention and stability. Both the intensity of the pressure and how the pressure is controlled to obtain the desired result depend on the proper use of available materials.

Studies have suggested that it is important to control the pressure during impression making.[11-14] Frank pointed out areas of the mouth requiring special attention regarding pressure control during impression making, and illustrated practical methods of increasing or decreasing pressure, as needed. Areas of the edentulous mouth requiring little pressure are the palate, residual ridges, and areas of easily displaced gingiva. More pressure is needed in the border seal area of the denture, on the buccal shelf, and against the retromylohyoid fossa.[11]

Frank reported major differences in pressures produced during maxillary edentulous impression procedures using various impression materials. Frank used a pressure gauge to test a regular mix of irreversible hydrocolloid, a thin mix of irreversible hydrocolloid, polysulfide impression material, and zinc oxide eugenol impression material. He also tested the effect of tray modification on the pressure produced. He noted that a tray border molded with modeling paste, with relief space and escape holes, met the requirements for selective pressure application. Zinc oxide paste was the final impression material of choice in most instances. It was concluded from his investigation that impression pressures could be controlled by tray design and material selection.[12]

Rihani measured pressures under maxillary edentulous impressions using manometers connected to the custom tray by flexible tubes. Impressions were made on three patients, each with a different palatal vault shape. Using zinc oxide eugenol, he found the highest pressure to be at the center of the palate.[13]

Komiyama evaluated changes in impression pressures produced by different types of relief and escape holes in the impression tray for making an impression. Silicone impression material, Exadenture, and a rigid simulated maxillary edentulous acrylic cast were used. Two measuring points were selected, the mid-palatal suture and the ridge crest. It was suggested that an escape hole 1.0 mm or larger, or a spacer with the thickness of a sheet of base plate wax, may be used to selectively reduce palatal impression pressure when making an impression of an edentulous maxilla.[14]

Masri analyzed pressures produced during maxillary edentulous impression procedures on the right ridge, left ridge, and the palate, using modern impression materials.[15] Final impressions with various tray modifications on an oral analog were made. A pressure gauge system to test irreversible hydrocolloid, light body vinyl polysiloxane, medium body vinyl polysiloxane, and light body polysulfide impression materials was used. The effect of the tray modification on the pressure produced during impression making was also tested. Masri found that all the tested impression materials produced pressure during maxillary edentulous impression making. Medium body vinyl polysiloxane and irreversible hydrocolloid produced the highest pressures while light body vinyl polysiloxane and light body polysulfide impression materials produced the lowest pressures. The use of light body vinyl polysiloxane and light body polysulfide is recommended to make maxillary edentulous impressions when the lowest pressure is desired. Tray modification was not important in changing the amount of pressure produced during impression making.[15]

The biologic considerations for mandibular impressions are generally different than those for maxillary impressions. The basal seat of the mandible is different in size and form from the basal seat of the maxilla. The submucosa in some parts of the mandibular basal seat contains anatomic structures that are different from those found in the maxilla. Moreover, the nature of the supporting bone on the crest of the residual ridge usually differs between the two arches. These variances are often sufficient to require major modifications in impression procedures for the mandible. The presence of the tongue and its size, form, and activity complicate the impression procedures for mandibular dentures and the patient's ability to learn to manage the denture.[16-18]

It is evident that it is important to study the effect of pressure during mandibular impression making, but to date no published reports have investigated this effect. The objective of this study was to measure the pressure exerted under simulated mandibular edentulous impressions using various impression materials and tray configurations.

Materials and Methods

In this study, the method described previously by Masri was adopted with certain modifications. An oral analog

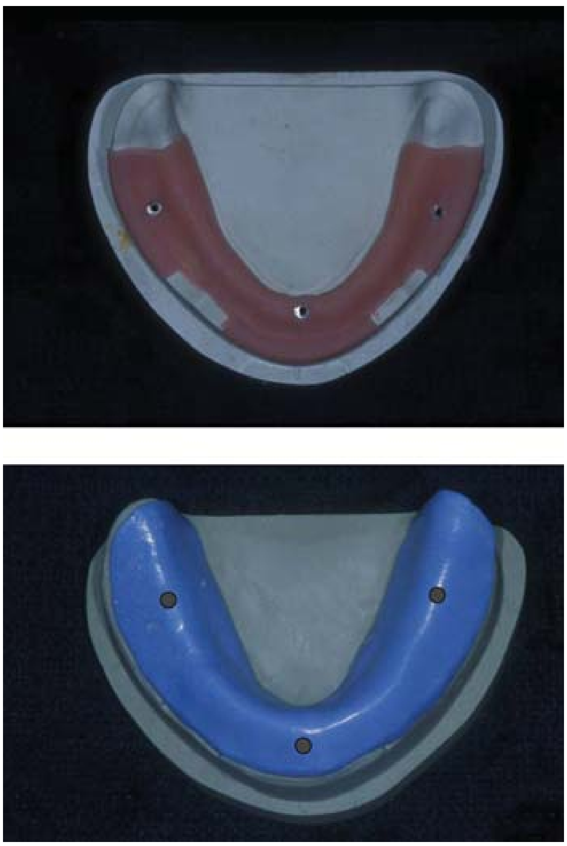

Figure 1. Oral analog—custom tray with 3 holes.

of an average size edentulous mandibular ridge was fabricated using a rubber model former (Columbia Dentoform Co. Long Island City, NY) (Fig 1). Vinyl polysiloxane (Gingitech, Ivoclar North America, Inc. Ontario, Canada) was used to provide a resilient surface layer simulating the soft tissues of the mandibular arch. Dental stone, type V (Die Keen, Heraeus Kulzer, IN), was used to fabricate the bulk of the oral analog. Three metal tubes (Tygon Flexible Plastic Tubing, Cleveland, OH), 2 mm in diameter and 25 mm in length, were placed in the model former and stabilized using sticky wax. An even thickness (4 mm) of vinyl polysiloxane was injected in the model former to establish an even thickness of resilient material, and type V dental stone was mixed according to manufacturer's recommendations and poured. The stone was allowed to set undisturbed for 45 minutes, and the oral analog was then removed from the model former.

Trays were fabricated with and without relief space. The oral analog was duplicated using reversible hydrocolloid (Nobiloid All Purpose Duplicating Material, Nobilium, Albany, NY) and poured into type IV dental stone. The resulting cast was used to fabricate custom trays without relief. A 2-mm wax sheath was applied to the oral analog to act as a spacer and to provide space for the impression material. The oral analog, with the wax spacer, was duplicated with reversible hydrocolloid material and poured using type IV dental stone as above. The resulting cast was used to fabricate custom trays with 2 mm relief.

The custom trays were fabricated on the replicas of the oral analog using the sprinkle-on method with blue auto polymerizing acrylic resin (Jet Acrylic, Lang, Wheeling, IL). The excess material was trimmed and the custom trays were left to polymerize undisturbed for 24 hours. Custom trays were fabricated to end flush with the oral analog land area to ensure positive and consistent seating. Holes were created on the same tray after testing of the first group was completed. Holes were placed on three locations (anterior, right, and left ridge) using a no. 8 round bur (Brasseler USA Dental Rotary Instruments, Savannah, GA).

Plastic tubes (Tygon Flexible Plastic Tubing) (2 mm diameter, 100 cm length) were attached to the embedded metal tubes in the oral analog. The oral analog was mounted on the lower half of a reline jig using type II dental stone. The custom tray was seated on the oral analog and mounted on the upper half of the reline jig using type II dental stone. The reline jig served as an orienting device to ensure accurate and repeatable seating of the custom tray on the oral analog and an even distribution of the applied pressure. The lower half of the reline jig with the oral analog was seated on the platform of the universal testing machine (Satec Material Testing Equipment, T 5000 Series, Scottsdale, AZ), and the plastic tubes were attached to the pressure transducers (Validyne Engineering Corp, Northridge, CA). The tubes were filled with distilled water and

Table 1. Impression Materials Used

Impression Material	*Manufacturer*	*Method of Mixing*
Polysulfide (Light body)	Permalastic, Kerr, Romulus, MI	Manual
Vinyl polysiloxane (Light body)	Extrude, Kerr	Auto
Vinyl polysiloxane (Medium body)	Extrude, Kerr	Auto
Irreversible Hydrocolloid	Jeltrate, Dentsply Caulk, Milford, DE	Manual

special attention was paid to avoid incorporating air bubbles in the tube. When the loaded trays were seated on the oral analog, the impression material applied pressure to the water in the tubes. This pressure was transferred through the tubes to the pressure transducers. The pressure transducers were calibrated by the manufacturer prior to the experiment.

Currently used impression materials were tested (Table 1) using four tray designs. The custom tray was filled completely with the impression material. Working time was based on the manufacturer's recommendation. The upper half of the reline jig, with the loaded custom tray, was secured in place on top of the lower half. A Satec universal testing machine was used to deliver a constant pressure of 1 kg/cm^2, while seating the loaded custom tray onto the oral analog. Pressure measurements were recorded through the metal tubes at three locations on the oral analog: anterior alveolar ridge, the right buccal shelf, and the left buccal shelf. The pressure of the right and left buccal shelf was averaged because both represent the same area, the primary stress area, and were at the same location in relation to the ridge.

Pressure measurements were recorded by three operators every 10 seconds until no change in pressure was detected and the impression material was completely set. Each operator recorded only one position of the oral analog, measuring the maximum pressure and the final pressure.

Sixteen impression material and tray design combinations were tested five times per combination. A total of 80 impressions were made. Data for each impression material-tray combination were obtained. Results were analyzed using factorial ANOVA and Tukey's HSD Test.

Results

There was a significant difference in pressure production among the different impression materials (Table 2, Fig 2). Irreversible hydrocolloid and medium body vinyl polysiloxane produced the highest pressures, which were significantly higher than the pressures produced by both light body polysulfide and light body vinyl polysiloxane. There was no significant difference in pressure between irreversible hydrocolloid and medium body vinyl polysiloxane. Also, no significant difference was found between light body polysulfide and light body vinyl polysiloxane.

There was a significant difference in pressure production among the four different tray designs (Table 2, Fig 3). A tray with no relief and no

Table 2. Three-Way ANOVA of Pressure Development Underneath Mandibular Complete Denture During Impression Making (Pressure in MPa)

	X ± SD	*F*	*P*
Main effects			
Impression material			
Light body polysulfide	0.007 ± 0.006^a	205.544	≤0.001
Light body vinyl polysiloxane	0.012 ± 0.009^a		
Medium body vinyl polysiloxane	0.560 ± 0.359^b		
Irreversible hydrocolloid	0.599 ± 0.388^b		
Tray design			
No relief no holes	0.517 ± 0.533^a	54.527	≤0.001
No relief with holes	0.241 ± 0.289^b		
Relief no holes	0.161 ± 0.254^b		
Relief with holes	0.186 ± 0.281^b		
Pressure location			
Anterior ridge	0.350 ± 0.437	22.920	≤0.001
Buccal shelf	0.240 ± 0.326		
Interaction effect			
Impression material × tray design		17.937	≤0.001
Impression material × pressure location		8.955	≤0.001
Tray design × pressure location		0.817	0.487
Impression material × tray design × pressure location		1.231	0.282

Groups modified with the same letter are not significantly different.

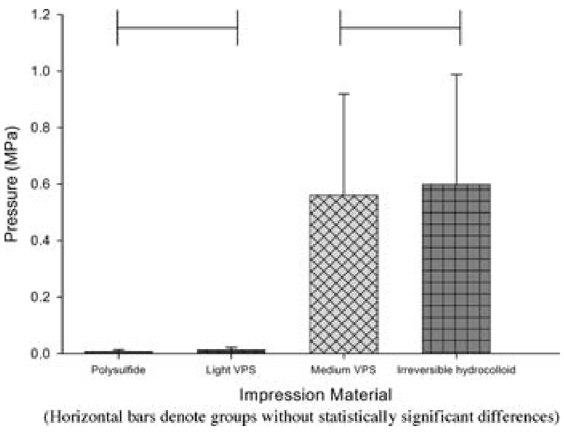

Figure 2. Pressure produced by different impression materials.

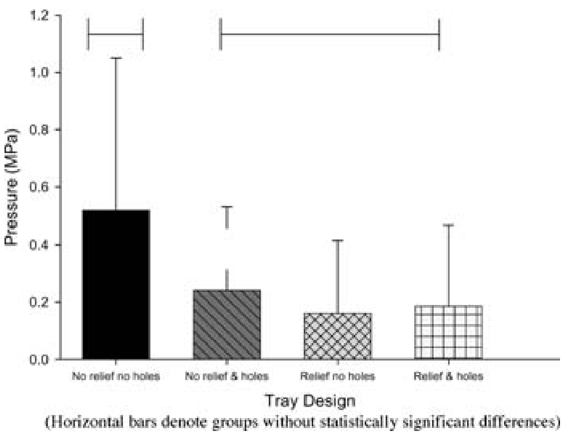

Figure 3. Pressure produced by different tray designs.

holes produced the highest pressure; this pressure was significantly higher than that produced by trays that had no relief with holes, relief and no holes, and relief with holes. No significant difference in pressure was found between the tray that had no relief with holes and the trays that had relief with and without holes.

When looking at the difference in pressure at different locations on the oral analog, higher pressure was observed at the anterior ridge when compared with the buccal shelf area (Table 2, Fig 4).

There was a significant interaction between impression materials and tray design (Table 2, Fig 5). The highest pressure was observed when using a combination of irreversible hydrocolloid and a tray with no relief and no holes while the least pressure was recorded when a combination of light body polysulfide and a tray with holes and relief

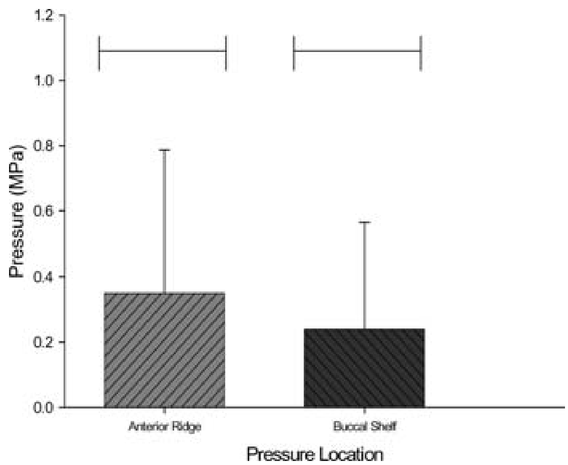

Figure 4. Pressure produced by different locations.

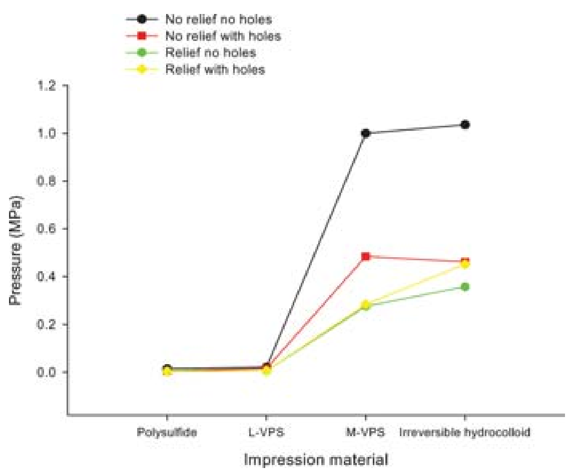

Figure 5. Interaction between impression materials and tray design.

was used. For medium body vinyl polysiloxane, the tray that had relief and no holes showed no significant difference in pressure when compared with the tray that had relief with holes. For irreversible hydrocolloid, the tray that had relief and no holes showed less pressure than a tray that had relief with holes; however, there was no significant difference in pressure found for light body polysulfide and light body vinyl polysiloxane when using any tray designs.

There was a significant interaction between impression materials and pressure locations (Table 2, Fig 6). For the anterior ridge, medium body vinyl polysiloxane produced higher pressure than irreversible hydrocolloid, whereas at the buccal shelf, irreversible hydrocolloid produced

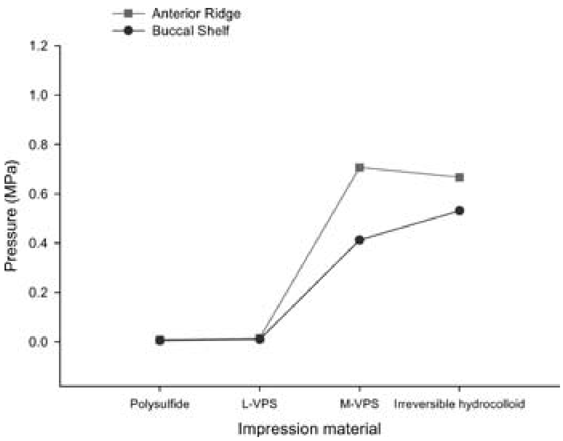

Figure 6. Interaction between impression materials and pressure locations.

higher pressure than medium body vinyl polysiloxane. There was no significant difference in pressures observed for light body polysulfide and light body vinyl polysiloxane in the anterior ridge as compared with the buccal shelf area, and no significant interaction between tray design and pressure locations was found (Table 2). All tray designs showed higher pressure at the anterior ridge than buccal shelf area.

Discussion

The tested materials can be categorized into two groups: a group that produced high pressure, which included irreversible hydrocolloid and medium body vinyl polysiloxane, and a group that produced low pressure, which included light body polysulfide and light body vinyl polysiloxane. The difference in pressure produced within each group was not statistically significant; however, the difference in pressure produced between the two groups was statistically significant and clinically important, which is in agreement with the finding of Masri.[15]

There appears to be a direct relationship between the viscosity of the impression material and the amount of pressure placed on the mandibular ridge during impression making. As the viscosity of the material increased, the pressure exerted upon the mandible increased as well. The medium body vinyl polysiloxane and irreversible hydrocolloid impression materials have higher viscosity and produced higher pressures than the light body polysulfide and light body vinyl polysiloxane impression materials (Fig 2).

The tray design also can be categorized into two groups: a tray that produced high pressure, which included only the tray with no relief and no holes, and a tray that produced low pressure, which included a tray with no relief but with holes, with 2 mm relief and no holes, and 2 mm relief and holes. The difference in pressures produced between the two groups was statistically significant and clinically important, which is similar to Frank's findings.

Masri suggested that the tray design was not clinically important in controlling the pressure produced in the maxilla[15]; however, tray modifications were important in changing the amount of pressure produced on the mandibular arch during impression making. In this study, the same tray was used for two different groups in order to decrease variability. This was accomplished by modifying the tray with the addition of holes after the testing of the first group was completed. The number and location of the holes of the tray differed among the studies and this may play a role in determining why the results from this study differ from those of Masri.[15] In the present study, three holes were placed in each tray; holes were placed on the anterior, right, and left ridges unlike in the investigation reported by Masri,[15] where five holes were placed in the rugae area and none were placed in the ridge area.

A difference in pressure was recorded on the anterior ridge, 0.1 MPa higher, when compared with the buccal shelf area on the mandibular arch. This may be due to the displacement of the impression materials toward the anterior ridge when making impressions. Clinically, the difference between the pressures produced at the two locations is very important because it may affect the final impression. Since the buccal shelf should be the primary stress-bearing area, the impression-making procedure should be modified in order to avoid a higher pressure being produced at the anterior ridge. In order to achieve this clinically, low-pressure impression materials, light body polysulfide and light vinyl polysiloxane, should be used because when these were used, there was no significant difference in pressure between the anterior ridge and the buccal shelf (Fig 6).

There may be several reasons why there is a difference in results between this study and that of Masri.[15] The main difference between the two studies is the arch tested. In addition, the pressure transducer used in this study was a different model than that used in the Masri study, and this may have played a role in the difference between the recorded numbers. Also, due to the fracture of the oral analog when the applied force was at 2 kg/cm^2, the Satec machine force was reduced from 2 kg/cm^2 to 1 kg/cm^2.

Both impression material and tray design were important in changing the amount of pressure produced on the mandibular arch during impression making only when medium body vinyl polysiloxane and irreversible hydrocolloid were used; however, light body polysulfide and light body vinyl polysiloxane showed neither statistically significant nor clinically important differences in producing pressure when using any type of tray design. The use of light body polysulfide or light body vinyl polysiloxane is recommended for making mandibular edentulous impressions. The fact that they produce the lowest pressure is important in the production of accurate impressions of minimally displaced mucosa. This will help in the fabrication of dentures that have proper retention, stability, and support.

Conclusion

All tested impression materials produced pressure during simulated mandibular edentulous impression making. Medium body vinyl polysiloxane and irreversible hydrocolloid produced the highest pressures; for them, tray modification was clinically important in changing the amount of pressure produced during impression making. Light body polysulfide and light body vinyl polysiloxane impression materials produced the lowest pressures; for them, tray modification was not important in changing the amount of pressure produced during impression making. A tray that had 2 mm relief or holes, or both, produced less pressure than one with no relief and no holes, especially for high-pressure impression materials. The use of light body polysulfide and light body vinyl polysiloxane impression materials is recommended for making mandibular edentulous impressions.

References

1. Heartwell CM, Rahn AO: Complete denture impressions. In Syllabus of Complete Dentures (ed 2). Philadelphia, Lea and Febiger, 1974, pp. 157-184
2. Zarb GA, Bolender CL, Hickey JL, et al: Biologic considerations for mandibular impressions. In Boucher's Prosthodontics Treatment for Edentulous Patients (ed 10). St Louis, Mosby, 1990, pp. 194-223
3. Bohannan H: A critical analysis of the mucostatic principle. J Prosthet Dent 1954;4:232-241
4. Addison PI: Mucostatic impressions. J Am Dent Assoc 1944;31:941-946
5. Collett HA: Final impressions for complete dentures. J Prosthet Dent 1970;23:250-264
6. Freeman SP: Impressions for complete dentures. J Am Dent Assoc 1969;79:1173-1178
7. Boucher CO: Impressions for complete dentures. J Am Dent Assoc 1943;30:14-25
8. Boucher CO: A critical analysis of the mid-century impression techniques for full dentures. J Prosthet Dent 1951;1:472-492
9. Tryde G, Olsson K, Jensen SA, et al: Dynamic impression methods. J Prosthet Dent 1965;15:1023-1034
10. Page H: Mucostatics: A practical comparison. Tic 1947, pp 2-10
11. Frank RP: Analysis of pressures produced during maxillary edentulous impression procedures. J Prosthet Dent 1969;22:400-413
12. Frank RP: Controlling pressures during complete denture impressions. Dent Clin North Am 1970;14:453-470
13. Rihani A: Pressures involved in making upper edentulous impressions. J Prosthet Dent 1981;46:610-614
14. Komiyama O, Saeki H, Kawara M, et al: Effect of relief space and escape holes on pressure characteristics of maxillary edentulous impressions. J Prosthet Dent 2004;91: 570-576
15. Masri R, Driscoll CF, Burkhardt J, et al: Pressure generated on a simulated oral analog by impression materials in custom trays of different designs. J Prosthodont 2002;11: 155-160
16. Atwood DA, Coy WA: Clinical, cephalometric, and densitometric study of reduction of residual ridges. J Prosthet Dent 1971;26:280-295
17. Faber BL: Retention and stability of mandibular dentures. J Prosthet Dent 1967;17:210-218
18. Jacobson TE, Krol AJ: A contemporary review of the factors involved in complete dentures. Part III: support. J Prosthet Dent 1983;49:306-313