Comparative evaluation of pressure generated on a simulated maxillary oral analog by impression materials in custom trays of different spacer designs: An *in vitro* study

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Abstract

Introduction: Literature reveals that masticatory load on denture bearing tissues through complete dentures should be maximum on primary stress bearing areas and least on relief area in accordance with the histology of underlying tissues. A study to validate the existing beliefs was planned to compare the pressure on mucosa using selective pressure technique and minimal pressure technique, with the incorporation of two different impression materials utilizing the pressure sensors during secondary impression procedure. **Materials and Methods:** The study was performed using a maxillary analog. Three pressure sensors were imbedded in the oral analog, one in the mid palatine area and the other two in the right and left ridge crest. Custom trays of two different configurations were fabricated. The two impression materials tested were light body and zinc oxide eugenol. A total of 40 impressions were made. A constant weight of 1 kg was placed, and the pressure was recorded as initial and end pressures. **Results:** A significant difference in the pressure produced using different impression materials was found ($P < 0.001$). Light body vinyl polysiloxane produced significantly lesser pressure than zinc oxide eugenol impression materials. The presence of relief did affect the magnitude of pressure at various locations. **Conclusion:** All impression materials produced pressure during maxillary edentulous impression making. Tray modification is an important factor in changing the amount of pressure produced. The impression materials used also had a significant role to play on the pressures acting on the tissues during impression procedure. **Clinical Implication:** Light body VPS impression material may be recommended to achieve minimal pressure on the denture bearing tissues in both selective as well as minimal pressure techniques.

Keywords: Impression material, pressure, pressure sensor, spacer, special tray

Introduction

The oral mucosa of edentulous patients is subjected to different magnitudes and varying nature of forces. These forces are necessary, but can be harmful at the same time. The insertion of a complete denture in an edentulous patient's mouth alters these forces and has its own effect on the edentulous ridges. The tissues are subjected to unnatural stresses by intimate contact with complete denture, and despite the best clinical efforts, the underlying supporting tissues often undergo degenerative changes in case of improper care by the patient. In most cases, these changes are felt to be caused by the improper distribution of functional forces in relation to stress bearing capacity of various areas of denture bearing mucosa.[1]

To achieve a longer functional life of ridge and the prosthesis, maintenance of the supporting tissues in a physiologic condition is a prime requisite when constructing an intraoral prosthesis.

The technique used in impression making has an important role in the reaction of supporting tissues to complete dentures[2] and thus impression is regarded as a critical step in determining the fit, esthetics, comfort, and efficiency of the denture. An ideal impression embraces all the edentulous areas to be used by the denture, embodying composite of the tissues at rest without any compression or displacement. Such an impression made with little or no pressure will ensure a positive adaptation of the denture. Thus, a decrease in

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pressure developed during impression making is an important factor in denture success.[3-5]

There have been surveys reporting widespread use of a variety of special trays, especially for the production of removable prosthesis.[6,7] Various materials and techniques have been considered for making complete denture impressions. These include selective pressure technique, the functional impression technique, and the mucostatic (nonpressure) impression technique.[8]

Many researchers believe that there is a direct effect of impression material as well as tray design on the amount of pressure on the underlying tissues and also those who do not.

The literature also reveals that masticatory load on denture bearing tissues through complete dentures should be maximum on primary stress bearing areas and least on relief area in accordance with the histology of underlying tissues. This objective is expected to be achieved using selective pressure impression technique.

Therefore, a need was felt to evaluate the effect of various impression materials and different tray designs on the pressures exerted on the denture bearing tissues. A study to validate the existing beliefs was planned to compare the pressure on mucosa using selective pressure technique and minimal pressure technique, with the incorporation of two different impression materials utilizing the pressure sensors during secondary impression procedure.

Aims and objectives

This study was conducted with the following aims:

- To measure pressure exerted on different areas of the maxillary analog during secondary impression procedure using two different tray designs
- To measure pressure exerted on different areas of maxillary analog during impression procedure using two different impression materials.

The objective of this study was to understand and evaluate the effect of two different impression materials and tray designs on the pressure exerted on various areas of denture bearing tissues.

Materials and Methods

This *in vitro* study conducted in the Postgraduate Department of Prosthodontics, Babu Banarasi Das College of Dental Sciences, Lucknow, using maxillary analog and different combinations of final impression materials and special trays of different spacer designs.

The pressure on different areas of denture bearing mucosa was gauged using the Force sensitive resistor (Model FSR400) diameter (active area of the resistor) of FSR was 0.2” (5.0 mm) and thickness was 0.012” (0.3 mm). A printed circuit board was used to mechanically support and electrically connect electronic components. A personal computer in the form of a display was used to obtain readings during the study.

Methods

An ideal maxillary edentulous cast was fabricated in type III dental stone (Kalabhai, Mumbai) using an edentulous mold. The cast was retrieved after its final set according to the manufacturer’s instructions. This maxillary cast thus obtained was trimmed and finished using a trimmer. A uniform thickness of soft liner was applied on the maxillary cast to fabricate a maxillary analog [Figure 1].

Duplication

The duplication of this maxillary analog in type IV dental stone was pursued with irreversible hydrocolloid (Zhermack, Germany) duplicating material which later was utilized to fabricate special trays of various designs of spacers. Total of two trays were fabricated for utilizing minimal pressure technique and selective pressure technique.

Fabrication of special tray

Minimal pressure technique

A single modeling wax sheet was adapted over the entire tissue surface of the duplicated cast. The wax sheet is then cut 2 mm short of the sulcus depth of duplicated cast. Four tissue stops measuring 2 mm × 2 mm were made in the spacer, two in canine region, and two in molar region bilaterally at the crest of ridge. The special tray was fabricated in resin.

An empty 2 ml syringe barrel was sliced into 3 parts at markings of 0.5 ml. Autopolymerizing acrylic resin (DPI, Fort, Mumbai) was mixed as above and filled into the cut syringe barrel and placed over the special tray to act as support for the weight to be placed on maxillary analog during pressure measurements.

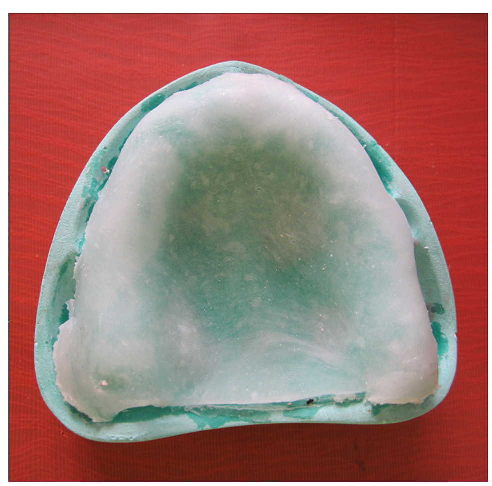


Figure 1: Maxillary analog with soft liner

The spacer wax was removed from the special tray, and relief holes of uniform diameter of 2 mm were made with a round bur throughout the special tray.

Selective pressure technique

Another tray was fabricated by adapting wax spacer over the cast in an "I" shape extending anteroposteriorly from incisive papilla to fovea palatine along mid palatine raphe, and then special tray was fabricated similarly as mentioned in minimal pressure technique.

The spacer wax was removed from the special tray, and relief holes of uniform diameter of 2 mm were made with a round bur in the mid palatal raphe region of the special tray.

Recording the secondary impression

Under controlled conditions of temperature and humidity, three FSRs (Interlink Electronics, Camarilo, CA, USA) were placed on the maxillary analog-two placed over the crest of ridge bilaterally at molar region and one placed at the center of mid palatine raphe region [Figure 2]. Two impression materials namely zinc oxide eugenol impression paste and light body (polyvinyl siloxane) were used for wash impressions.

The zinc oxide eugenol impression paste was carefully loaded onto the special tray, and one kg weight was placed on the loaded tray over the analog [Figure 3]. The pressure readings were noted in all the three pressure sensors from the time of placement of tray till material was finally set. Similarly, light body addition silicone was also used for making final impressions with both the trays as per manufacturer's instructions.

Total of forty samples were made as per following distribution

Grouping of samples

Readings were noted immediately after the placement of loaded special tray on maxillary analog denoted as initial pressure and then readings were noted after final set of impression materials denoted as end pressure for each sample of different groups. For each sample, three readings at locations S1, S2, and S3 were recorded.

The observations were tabulated and subjected to statistical analysis (The Kolmogorov–Smirnov test, Mann–Whitney U-test, The Wilcoxon signed rank statistic, etc.). The results of the comparisons are as follows.

Results

Total of 40 samples were evaluated [Figure 4]. Evaluations were made at three different locations and at two different time intervals as follows:

On comparison of pressure at different locations (S1, S2, and S3) between initial and end pressure (minimal pressure application), at all locations initial pressure were found to be significantly higher than end pressure at that location ($P = 0.005$) [Graph 1].

On comparison of Group I and II, a significant difference in pressures between the two groups was observed at S1 and S2 locations where values in Group II were observed to be of lower order as compared to that of Group I ($P < 0.05$) [Graph 2].

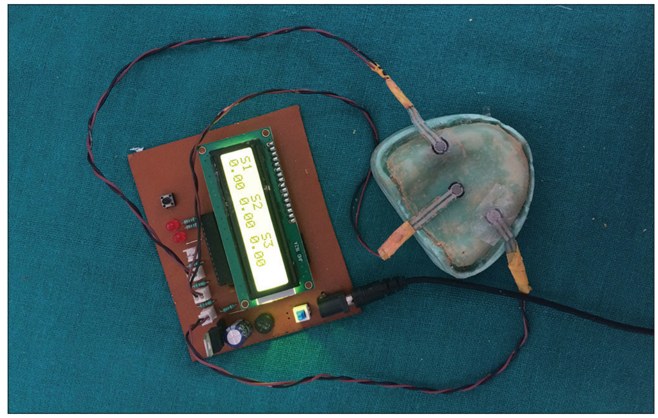


Figure 2: Three pressure sensors placed on maxillary analog with digital display

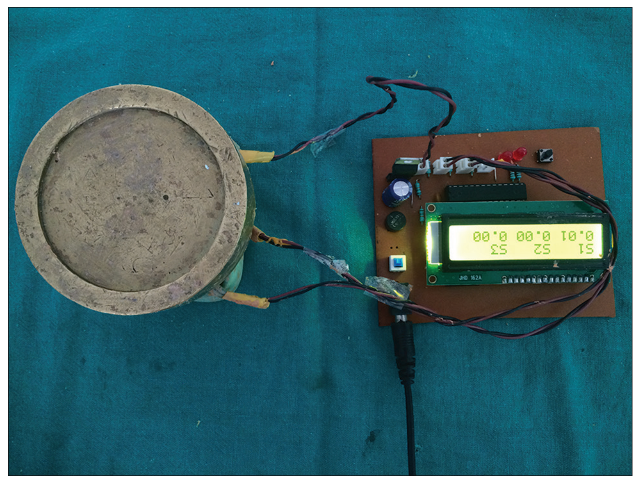


Figure 3: 1 kg load placed on loaded tray over maxillary analog

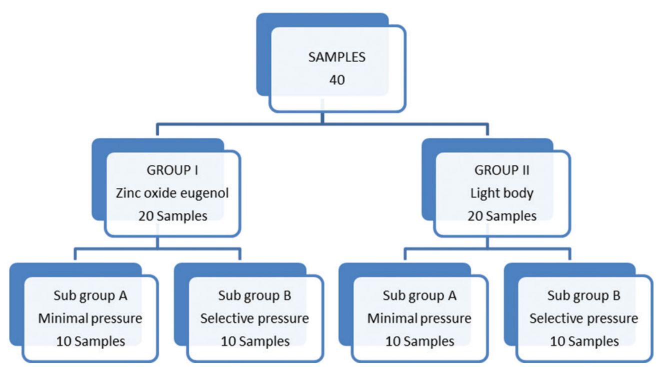
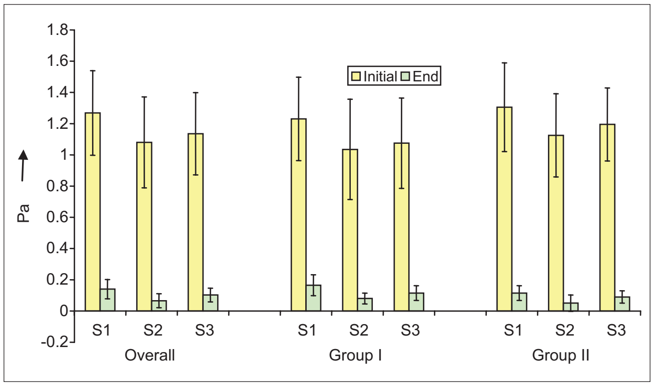


Figure 4: Grouping of samples

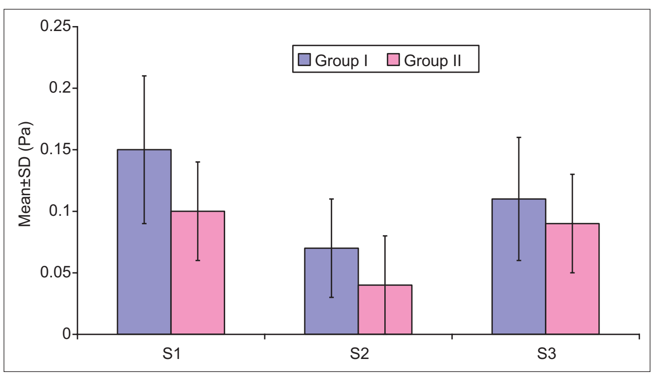
On comparison of selective pressure at different location, overall as well as for different combinations, mean end pressure was maximum at S1 and minimum at S2. Statistically, intergroup differences were found to be significant [Graph 3].

Discussion

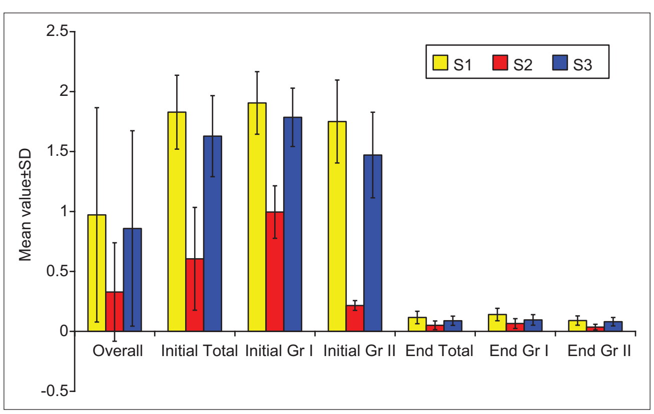
The important objectives namely retention, stability, support, esthetics, and preservation of the residual alveolar ridges of complete denture impressions as outlined by Boucher seem to be quite adequate.[7] These objectives can be best fulfilled by a thorough understanding of the oral anatomy and histology of the patient and by an impression technique and material that will most accurately record these structures with minimal displacement of tissues.[8]



Graph 1: Comparison of pressure at different locations (S1, S2, and S3) between initial and end pressure (minimal pressure application)



Graph 2: Between group comparison of pressure at different locations (S1, S2, and S3) (end pressure)



Graph 3: Comparison of selective pressure at different locations

The application of pressure during an impression procedure can be partly due to the viscosity of the impression material[9] and partly due to the approximation of the tray to the oral tissues. Pressure, a boon and a bane, is an integral part of an impression. Pressure makes the material flow and facilitates intimate tissue contact. This intimate tissue contact aids in fulfilling a very important objective of impression making that is retention.

On application of pressure, there is mucosal displacement after which a strained equilibrium is established, and alveolar bone is subjected to tensile and shear stresses.[10] These stresses cause harmful effects on the alveolar bone even leading to accelerated resorption.[11,12] A registration other than at rest should be for purposes of expediency only, for alveolar bone is best preserved with rest registrations.[13,14]

There has been a considerable disagreement regarding the placing of pressures, relief, and post dams in maxillary impressions.[15] The crest of the upper ridge is considered as a stress bearing area as it is covered with fibrous connective tissue, which is closely attached to the bone. The greater palatine foramen does not need relief because it is deep under palatal glands in a groove in the maxillary bone. On the other, the median suture where the two maxillary bones join together is covered with mucous membrane and very little submucosal tissue. Hence, they should be relieved of pressure.[16] All these considerations are required in a selective pressure technique.

As seen in literature, it has been repeatedly said that the pressure exerted by the denture should be in accordance with the underlying tissues for the maximum preservation of tissues, leading to the development of various methods to selectively minimize pressure on tissues.[17,18] According to page, soft tissues should be registered in an impression in the unstrained rest position as any other position will compel the tissues to try to regain their rest position leading to dislodgement of the denture.[19]

Woelfel concluded in his study that the placement of spacers and escape holes in an impression tray are far more important factors in producing an excellent final impression than is the choice of a corrective wash material. He reinforced that the tray should be modified differently to meet the requirements of the specific type of wash material used.[20]

Hence, this study was undertaken to evaluate the pressures generated upon the edentulous maxillary residual ridge and the palate using minimal pressure and selective pressure impression procedures with two impression tray modifications and two types of impression materials.

Zinc oxide eugenol impression paste was used for wash impression in the study, as it has been a commonly used impression material with satisfactorily functioning denture.[8]

The second material used was light body addition silicone, which is well known to exert less pressure on the underlying tissues and record excellent details.[21] Similar kind of study was done by Masri *et al*. in 2002 using pressure transducers.[22]

In our study, we found that in minimal pressure application, for both impression materials, there was a statistically significant pressure difference between the S1 and S2 locations (both initial and end pressures), but statistically insignificant difference between S2 and S3 with pressure at S1 being 0.70 MPa and pressure at S2 being 0.57 MPa while at S3 being 0.61 MPa [Graph 1]. The difference at these three locations was practically insignificant in terms of pressure scale.

While in selective pressure technique, the pressures measured at S1 and S3 (crest of the ridge) (0.9 MPa) were significantly higher than those measured at S2 (mid palatine raphe region) (0.3 Mpa) [Graph 2]. This could be attributed to the placement of relief holes at mid palatine raphe region and absence of relief holes at the crest of the ridge.[23]

The pressures recorded with zinc oxide eugenol impression paste were significantly higher than those recorded with light body addition silicone in both minimal pressures as well as selective pressure technique. The pseudoplastic property of light body causes its viscosity to decrease with increasing strain rate. Hence, when force is applied over the material, it tends to flow more.[24] This property might be leading to lesser pressure exerted by it than those exerted by zinc oxide eugenol impression paste.

In 1925, Rihani measured pressures under maxillary edentulous impressions using manometers connected with flexible tubes to the custom tray. Using zinc oxide eugenol, Rihani found the highest pressure at the center of the palate. These findings were similar to the beliefs of Stansbury that the pressure is greatest at points farthest from the impression escapement and gradually becomes less until the point of escapement is reached.[25]

However, our findings were supported by Frank. In unrelieved custom trays, the pressure was greater over the ridge crest than over the palate.[23]

On comparing all our samples, initial pressures at all the locations were found to be higher than the end pressures and this difference was found to be statistically highly significant ($P < 0.001$) [Graph 3]. The reduction of end pressures with the placement of relief holes and variation in spacer design can be attributed to the fluid nature of impression materials. The impression material acts as fluid and the approximation of special tray to the underlying mucosa simulates a closed space, but due to the presence of escape holes and space at the periphery of the tray the material begins to flow out, hence reducing the pressure with time. As soon as the loaded tray is placed on the tissues with a weight on it, it exerts maximum pressure due to its highest volume. However, as the material is a fluid, it begins to flow under the weight (hand pressure) owing to its own low viscosity ending up in a thin film over the tray and soft tissues and consequently the pressure on the underlying tissues begins to reduce until it becomes negligible depending on the flow and viscosity of the material.

The above results show that minimal pressure could be best achieved with the use of light body addition silicone material.[21,22]

However, in Masri *et al*.'s study, it was found that tray modification was not important in changing the amount of pressure produced during impression making. Contrary to our study, Masri *et al*. believed that the tray design was not clinically important in controlling the pressure produced.[22]

However, as per our study, the role of varying the spacer design or placing escape holes in the special tray as well as the choice of impression material has been significant on the pressure which determines the state of tissues below the denture.

Conclusion

On the basis of the present *in vitro* study, the following conclusions have been drawn:

- In the minimal pressure technique, the difference of pressure at different locations of denture bearing area is practically insignificant
- In the selective pressure technique, the pressure is significantly higher at the crest of the ridge (stress bearing area) than at the mid palatine raphe region (relief area)
- The pressures recorded with light body addition silicone are lower than those recorded with zinc oxide eugenol impression paste at 3 locations.

In nut shell, we may conclude that the design of spacer and the use of escape holes as well as the type of impression material have a significant influence on the pressure exerted on the denture bearing tissues during the secondary impression procedure.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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