Changing the bonding force of impression tray to edentulous maxillary jaw simulator with impression valve system: *In vitro* study

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Abstract

Objective: The aim of this study was to evaluate the effect of an impression valve system (IVS) on the bonding force between an impression tray and an edentulous maxillary jaw.

Materials and Methods: In this *in vitro* study, a polyether-coated maxillary jaw simulator (PM) was used to model an edentulous maxillary jaw. The IVS was placed into individual impression trays. An irreversible hydrocolloid impression was taken of the PM when the IVS was open and closed. The impression tray bonding force was measured using a digital dynamometer. Student's *t*-test was used to determine the significance of the difference between these two groups.

Results: The impression tray was more easily separated from the PM when the IVS was open (108 ± 3.9 N). The separation was more difficult when the IVS was closed (153.7 ± 14.2 N). The difference between these two findings ($P = 0.000$) was significant.

Conclusion: The use of an IVS facilitates the removal of the impression tray from the mouth when taking impressions from an edentulous maxillary jaw.

Key words: Bonding force, impression tray, maxillary jaw

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Introduction

The purpose of complete dentures is to restore the dental and alveolar structures.[1] The first step in the restoration of these structures is selection of an appropriate impression material. Patient characteristics and the physical properties of the impression material play a crucial role in this decision. Selection of improper impression materials may negatively affect the adaptation and function of complete dentures. Common mistakes made, while producing the impression are as follows: Lack of impression tray rigidity, separation of the impression material from the tray, using improper impression materials, improper mixing of the impression material, and impression material tearing.[2]

While reproducing the edentulous tissue structure, it is important for the impression material to remain in the tray and to prevent tray deformation during the removal.[3] Numerous studies report inappropriate impression material adhesion to the tray.[2,4-6] Bomberg *et al*.[7] reported that the bonding of the impression material to the tray could be chemically or mechanically enhanced accurately and precisely to produce a dental prosthesis. Ona *et al*.[2] showed that chemical tray adhesives increased the bonding strength of the impression material to the tray. Marafie *et al*.[5] reported that chemical tray adhesives caused severe health problems such as irritation of the ear, eye,

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nose, and throat as well as headache, drowsiness, nausea, and dermatitis.

Physical and chemical factors contribute to impression material bonding with the oral mucosa. Impression material adhesion is created by interactions between the impression material and the keratin in the oral mucosa. Examples include hydrocolloid, polysulfide, and polyether impression materials. In addition, oral anatomic factors, such as tissue undercut, rugae, and the torus, as well as mechanical factors, such as cohesive forces, hydrostatic pressure, and negative pressure affect adhesion.[8]

Çalıkkocaoğlu[8] stated that a concave meniscus was formed with a decrease in the gap between the denture base and mucosa. This led to a difference between the prosthesis-mucosa pressure and the external pressure.[9] This negative pressure difference may also occur between the impression material and the mucosa, subsequently obstructing tray removal.

A review of the literature revealed a lack of reports evaluating the pressure difference between the impression tray and the edentulous maxillary jaw using a digital dynamometer.

The aim of this study was to evaluate the effect of an impression valve system (IVS) on the impression tray bonding force to an edentulous maxillary jaw.

Materials and Methods

An edentulous maxillary jaw simulator phantom model (PM) was used to model an edentulous maxillary jaw (Frasaco, Kemal Dental Store and Medical Production Co. Istanbul, Turkey). A 2-mm-thick polyether coating (3M ESPE, Duosoft Impregum, Seefeld, Germany) was applied to the PM to simulate soft tissue. The PM was placed in a Teflon mold filled with condensed silicon [Figure 1]. After the PM had been removed from the mold, the entire surface was carefully abraded forming crampons 2 mm in diameter and depth.

The polyether impression material was mixed according to the manufacturer's instructions and was poured into the mold. The PM was placed in the mold, and polyether material was given 10 min to set before the PM was removed. Excess material was removed, and the surface was carefully examined for porosity [Figure 2].

Preparing individual impression trays

Individual impression trays were prepared in accordance with the manufacturer's instructions using a light-cured resin plaque (DurabaseLC, Bolzano, Italy) on the PM. Anatomical structures were taken into consideration during this process. Four holes 2 mm in diameter were drilled on the inner surface of the impression tray. The IVS was placed into these holes using a flowable resin composite (Premise Flowable, Kerr Corporation, USA).

Impression valve system

The IVS relies on the release of negative pressure between the tissue surface and the impression material. The IVS consists of two main parts, the body and pin. The body consists of the following parts: The tissue stopper (1), the retention area (2), the air channel (3), and the external channel (4) [Figures 3 and 4].

The tissue stopper is the only portion facing the impression surface and creates an uniform thickness of the impression material in the tray. The IVS is attached to the impression tray via the retention area. The air canal allows the installment of the IVS pin. The external canal aids the positioning of the IVS within the tray. The IVS was considered "closed" when the pin was within IVS and "open" when the pin was out [Figures 5 and 6].

Following IVS installation, four stainless steel rings were fixed on the front and rear of the alveolar ridge of the tray to which the digital dynamometer was attached. These rings were fixed to the alveolar ridge with cold acrylic resin.

Digital dynamometer

A digital dynamometer (SUNDOO SH-500 Digital Dynamometre, Sundoo Instruments, China) was used to measure the bonding force [Figure 7]. The dynamometer parameters were as follows: Measurement unit, Newton (N) and method of measurement, peak value. The dynamometer was connected to the impression tray with orthodontic ligature wire. The tensile force used to measure the bonding force was applied perpendicularly to the palatal surface of the model.

Before taking the impression, the tray adhesive (Universal Adhesive, GC, Tokyo, Japan) was applied to the inner surface of the impression tray and was allowed to cure for 5 min. An alginate irreversible hydrocolloid was used as an impression material (Kromopan, Lascod Spa, Italy). The impression material was mixed according to the manufacturer's instructions in the automatic mixer (Algimax-II GX-300, Monitex Industrial Co. Ltd., Italy) for 6 s with 1:1 powder: Water proportion. Before the tray was placed on the model, artificial saliva was applied to the PM. The same researcher placed the impression trays on the PM by pressing on the alveolar ridge with two fingers. The excess impression material was removed digitally. The tip of the digital dynamometer was attached to the hooks on the impression tray with orthodontic ligature wire. A tensile force (F) was applied perpendicularly to the PM, and the maximum force at which the impression tray separated from the model was recorded in Newtons (N). A total of 40 measurements was conducted with the IVS open and closed.

Figure 1: Placing the phantom model into the Teflon mold

Figure 2: Polyether-coated phantom model

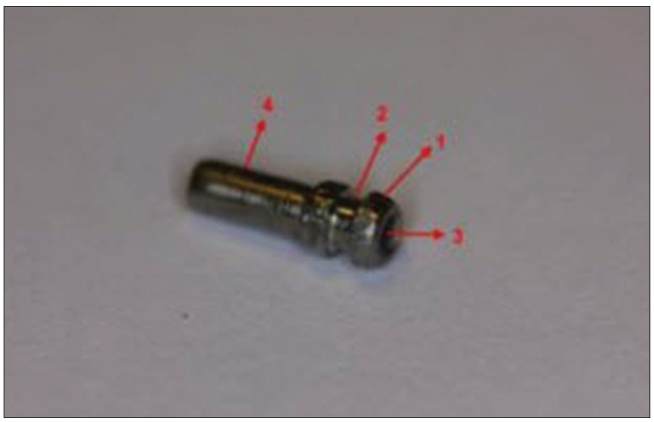

Figure 3: Impression valve system. Tissue stopper (1), retention area (2), air channel (3) and external channel (4)

Figure 4: Pin of impression valve system

Figure 5: Impression valve system with open state

Figure 6: Impression valve system with closed state

Statistical analysis

Statistical analyses were performed using SPSS version 15 (SPSS Inc., Chicago, IL, USA). Visual (Normal quantile-quantile plot) and analytic (Shapiro–Wilk) methods were used to evaluate whether the variables had a normal distribution. The two independent groups were compared using Student's *t*-test (α =0.05).

Results

The bonding forces are shown in Table 1. These data had a normal distribution according to the Shapiro–Wilk test. Student's *t*-test was used to determine if the difference between the two groups was significant. The effect of the

Figure 7: Connection of the digital dynamometer to the impression tray with orthodontic ligature wire

Table 1: Group statistics according to tensile force (*F*=Newton)

IVS conditions	X_{ort}	SD	Minimum *F*	Maximum *F*	*P*
IVS closed	153.7	14.2	130.5	180.2	<0.001
IVS open	108	3.9	101.6	114.3	<0.001

IVS=Impression valve system; SD=Standard deviation

IVS being open on the impression tray bonding force was statistically significant ($P = 0.000$). Summarizes the findings after the tensile force was applied.

The greatest bonding force was recorded when the IVS was closed (153.7 ± 14.2 N). The lowest bonding force was detected when the IVS was open (108.0 ± 3.9 N). This shows that the IVS had a significant effect on the bonding force ($P = 0.000$) [Figure 8]. When the IVS was open, the bonding force was 101.6-114.3 N. When the IVS was closed, the bonding force was 30.5-180.2 N.

Discussion

This *in vitro* study evaluated the effect of a new apparatus, the IVS, on the bonding force between the impression tray and an edentulous jaw. We found that the bonding forces when the IVS was open were significantly lower than those with the IVS closed ($P = 0.000$).

The literature regarding the surface pressure applied by the impression tray on edentulous jaws is limited, and previous studies used gypsum models to determine the pressure applied by the impression tray on the palate surface.[10] Data from gypsum models cannot simulate oral soft tissues. In this study, we used a 2 mm thick polyether coating on the PM to simulate the oral tissues. Moreover, artificial saliva was used between the impression material and the polyether coating to simulate conditions more realistically and enable the formation of cohesive forces.

A digital dynamometer was used to measure the negative pressure between the impression material and the artificial tissue. Sato *et al.*[11] used an occlusal force meter to study the

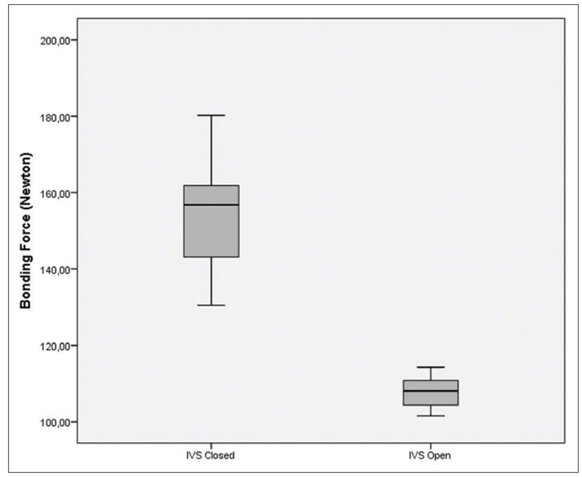

Figure 8: The box-plots show that the bonding force of impression tray to maxillary jaw ($P = 0.000$)

effectiveness of the prosthetic adhesives. Psillakis *et al.*[12] used a gnathometer to compare the bonding of prosthetic adhesives. We used a digital dynamometer in this study due to the following advantages: 0.01 measurement precision, ease of use for both oral and external measurements, computer connection via an RS-232 cable, and the recording of peak values.

Alginate is commonly used as an impression material to produce complete dentures.[13] Masri *et al.*[10] conducted a study with a gypsum maxillary jaw simulator, and reported that irreversible hydrocolloids, prepared appropriately, exerted the highest pressure on edentulous maxillary jaws. Therefore, we used alginate as the impression material in this study. All impression materials should be prepared and applied carefully. An automatic mixer was used to mitigate human error. The IVS stopper feature ensured the uniform impression material thickness along the entire tray. Four IVS systems, two on the right and two on the left, were used in close proximity to the alveolar ridge.

The bonding of the impression material to the tray is an important factor.[14] The material must bond to the tray firmly as the impression is taken. It also must not be deformed as it is removed. To achieve this, several alterations were made to the tray, including the addition of retention holes. It has been reported that impression tray adhesives and retention grooves increase the bonding force.[15] Çalıkkocaoğlu[8] reported that negative pressure, cohesive forces, and marginal sealing played important roles in the bonding of the complete denture base to the maxillary jaw. We used an impression tray adhesive to increase the bonding force of the impression material to the tray. The adhesive also prevented bonding failure resulting from impression material tearing during removal. In addition, we used artificial saliva between the impression material and the PM to simulate cohesive forces. We found that the negative pressure formed between the palatal surface and the impression material had a significant effect on the impression tray separation. To the best of our knowledge, there are no previous reports of the bonding force between the impression materials and the edentulous maxillary jaw. We developed the IVS to evaluate the bonding force and facilitate the impression tray removal. We used four IVSs applied to the alveolar ridge because the pressure on this structure was highest. This also ensured that the IVSs were symmetrical within the impression tray.

The maximum bonding force of the impression tray was 153.7 ± 14.2 N when the IVS was closed and 108 ± 3.9 N when the IVS was open. These findings show that the negative pressure formed between the palatal surface and the impression material has a significant effect on the bonding force. Discharging the negative pressure with the IVS facilitates the smooth removal of the impression tray.

Conclusion

This novel IVS, developed to change the bonding force between the impression material and the edentulous maxillary jaw, substantially facilitated the separation of the impression tray from the PM. Moreover, this is the first study to determine the bonding force between the impression tray and the jaw using a digital dynamometer. Future studies should determine the optimal number of IVSs.

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