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INTRODUCTION

Removable partial dentures (RPDs) remain a valuable service in dentistry. They have been a viable treatment option since the 1920s. The concepts and materials for the fabrication of RPDs, such as the Kennedy classification system, hydrocolloid impression materials, and surveying master dental casts, have not been changed much and they are still in use today[1]. While the advances of dental implants have made it possible to restore partially edentulous spaces with fixed dental prostheses, the affordability of RPDs still makes them a sustainable and invaluable service in dentistry for a large segment of the US population[1].

One of the main concerns to use RPDs is the questionable fit and accuracy[1,2]. The fit of RPDs is commonly evaluated by measuring intimate contacts or gap space between the RPD frameworks and their supporting structures including hard and soft tissues[1,3,4,5]. This intimate contacts between the supporting structures and the frameworks aid the stability and retention of the RPDs. Subsequently, it may affect the comfort of the prostheses during their use in the oral cavity. Unfortunately, it is estimated that 76% of RPDs do not fit properly[2]. Ill-fitting RPDs can cause a wide range of problems such as plaque accumulation, tooth mobility, root caries, oral candidiasis, tooth mobility, tooth rotation and ridge resorption[6].

The fabrication errors of RPDs, both in the clinic and laboratory settings, often lead to a decreased fit and accuracy of the RPD cast frameworks[3,4,8]. According to Abdelfattah, common causes of a misfit of cast metal frameworks include the inappropriate lab works, improper impressions and ridge changes following denture delivery[4]. Lanier et al cited poor mouth preparation, inaccurate master casts, errors in blockout and duplication, difficulty in obtaining sufficient expansion of the refractory, and the techniques used in fitting and finishing the metal framework[7]. Framework alloys have a shrinkage: cobalt-chromium (Co-Cr) alloys have the greatest shrinkage, followed by nickel-chromium (Ni-Cr) alloys. Type IV gold alloys (not commonly used) have the least shrinkage[3].

As mentioned earlier, improper impressions will lead to inaccurate master casts, ultimately ill-fitting RPDs. Two elastomeric impression materials that are commonly used in RPD fabrications are alginate and polyvinylsiloxanes (PVS)[6]. Alginate is an irreversible hydrocolloid material that has many advantageous properties, such as low cost, accuracy, hydrophilicity, that enable an acceptable replication of the mouth[6]. However, its disadvantages include dimensional instability, sensitivity to time and temperature, imbibition and syneresis[6]. Therefore, alginate impressions must be poured quickly.   Polyvinylsiloxanes

(PVS), also known as addition reaction silicones, are a dimensionally stable alternative to alginates. PVS materials provide accurate detail, less distortion, low polymerization shrinkage, longer working time, a high tear strength and hydrophilicity[6].

Recently, digital impression (scanning) has been added in literature to the RPD fabrications[5]. Digital scanning, intraorally at chairside setting for single tooth, partial or full arch or extraorally at dental laboratory on dental casts or intraoral impressions, can create an accurate 3-dimentional rendering the patient's soft and hard tissues for fabrication of dental prostheses. The scanned images can be formatted into a standard tessellation language (STL) file, which can then be forwarded to a distant dental laboratory via the internet or in an external storage device. A recent study has shown that digital impressions using intraoral scanners are comparable to impressions made using PVS impression materials[5].

The purpose of this study is to evaluate which impression material (alginate, PVS or digital impression) will produce the best fit accuracy of the RPD frameworks.

The null hypothesis is that there is no difference in the fit accuracy of RPD frameworks using different impression materials.

MATERIALS AND METHODS

This in-vitro study was conducted in four phases: (1) fabrication of 3 identical partially edentulous models to simulate a patient's soft and hard tissues, (2) fabrication of final impressions for the RPDs (alginate, PVS and digital impressions) and their master casts, (3) fabrication of the cast RPD frameworks and (4) measuring fit accuracy of the RDP frameworks to the edentulous models. (Fig 1).

A maxillary partially edentulous hard typodont model (Kilgore International, Inc. Coldwater, MI) was custom-made by the manufacturer to the specification of a Kennedy class III modification I, missing teeth #3, #4, #12, #13 and #14 (Fig 2). Modifications, in order to create rest seats and guide planes, were made on abutment teeth #2, #5, #11 and #15 (Fig 3) as per the author's RPD prescription (Fig 4). Then, the modified typodont was returned to the manufacturer (Kilgore International, Inc. Coldwater, MI) for duplication of three identical models. (Fig 5). These duplicated models were to simulate the hard and soft tissues of the oral cavity for three groups of dental impressions: Alginate (Group 1), PVS (Group 2) and Digital Scan (Group 3).

At standard room temperature, five alginate impressions (Type I Alginate Henry Schein, Melville, NY) were made with metal stock trays from a duplicated model (Group 1). Five PVS impressions (Kerr Heavy and Light Body PVS, Brea, CA Lot: 19-1094 and 18-1214) were made on another duplicated model with custom trays (Triad, Dentsply, Charlotte, NC) (Group 2). All of the impressions were boxed and poured in type V dental stone (Die Keen, Heraeus Kulzer, Armonk, NY). The master casts were allowed to set for 45 minutes as per the manufacturer's recommendation before removal from the impressions. After separation from the impressions, the master casts were then allowed to set on a bench top for additional 24 hours. After they were individually numbered, the master casts were packaged to be shipped to a commercial dental laboratory for fabrication of ten RPD frameworks. (Fig 6) Five digital impressions (Group 3) were made from the third duplicated model with a calibrated CEREC Primescan Intraoral Scanner (version 5.0.1 CEREC SW software, Sirona, Charlotte, NC). (Fig 7) A separate file folder was created for each individual digital impression. The five digital impressions were saved as Standard Tessellation Language (STL) format. These file folders were then exported onto an external portable storage device. The master casts (Group 1 and 2) and digital impressions (Group 3) with the laboratory order for 15 RDP frameworks were shipped to the dental laboratory. A single dental laboratory technician fabricated all the prostheses.

At the dental laboratory, the ten master casts for Group 1 and 2 were analyzed, surveyed and blocked for undercuts by the dental laboratory technician. Then, they were duplicated in refractory materials for waxing up for frameworks later.   The five digital impressions in Group 3 went through the same steps digitally, utilizing the DentalCad design software (Exocad, Woburn, MA). Five master casts for Group 3 and five digitally designed framework patterns were 3-D printed by a 3-D printer (Asiga 3D printer, Whipmix, Louisville, KY) with a specific printer resin (Veribuild resin, Whipmix, Louisville, KY). Then, all 15 frameworks were conventionally sprued, invested and cast using the lost wax burnout technique. The frameworks were fabricated in Wironium Cobalt Chromium alloy (BEGO USA, Inc., Lincoln, RI). This alloy has a composition of 63% Cobalt, 29.5% Chromium, 5% Molybdenum and less than 1% composition of several other metals.

After the 15 RPD frameworks were returned to the investigator, they were inventoried and labeled while still on their master casts (Fig 8). Prior to trying in the frameworks on the duplicated custom models, they were inspected in random order for the following parameters: Is adjusting the framework necessary to achieve a passive fit (Yes or No)? If ‘yes”, how much time was necessary for adjustments. They were recorded in the Table 1. The adjusted areas in the frameworks were not re-polished.

Each RPD framework had a total of 34 (16 sites from teeth #2 and #5 and 18 sites from teeth #5 and #11) sites for fit accuracy measurements (Fig 9 and Fig 10). These sites were marked on the outside surface of the framework with a permanent black marker. Three measurements at each marked site (alloy only) were made with a digital caliper (model 657-100, Dyer Corp, Lancaster, PA) (Fig 11). Then, the average values of them were recorded. Following the initial measurements, PVS bite registration material (Blu Mousse, Parkell, Brentwood, NY, Lot: 1933619336) was injected onto the abutment teeth on the duplicate custom model. The RPD framework was fully seated by finger pressure. (Fig 12) Once the PVS material had set, the RPD framework along with the PVS material was removed from the model. After inspecting the intaglio surfaces of the clasp assemblies, excess PVS material was carefully removed with a sharp #15 scalpel blade. The intaglio surfaces that had direct contact to the abutment teeth were identified with the permanent marker. All the previously 34 marked sites on the RPD frameworks, now with the PVS material, were re-measured with the caliper in the same manner. The gap space was determined by subtracting the measured thickness of alloys from those of alloys and PVS material. In other words, the gap space was the distance between the framework and the abutment teeth. The resulting data files were imported to an Excel spreadsheet (version 2004, Microsoft Corp, Redmond, Washington). A total of 510 measurements of gap spaces (Fig 13) from specimens (15 RPD frameworks) made from 3 impression materials (Group 1, 2 and 3) were sent to a statistician for analyses. The Shapiro-Wilk test was used to assess the normality of the data distribution. A one-way Analysis of Variance was conducted to compare the difference in the fit between the three groups (alginate, PVS, digital scan). Pearson correlations were used to assess the relationship between contact and fit. Significance was declared at $P<0.05$ for all tests. All data was analyzed using SPSS version 25.0 (SPSS, Chicago, IL).

RESULTS

During the try-in of the RPD frameworks, no specimens from Group 3 (digital impression) required adjustment, while the other group specimens required adjustments (Table 1).

Overall, Group 3 (digital impression) demonstrated the smallest gaps (269.6 µm) in the clasp assemblies of the RPD frameworks, followed by Group 2 (PVS impression group with 287.2 µm), and lastly Group 1 (alginate group with 296.9 µm) (Table 2). However, Group 2 demonstrated the smallest gaps at the rest seats (256 µm), followed by Group 1 (267 µm), and lastly followed by Group 1 (269.6 µm). However, there was no significant statistical difference in fit accuracy (i.e. gap spaces) between alginate, PVS or STL RPD groups, $P=0.93$. The gap spaces on abutment teeth (#2, #5, #11 and #15) are recorded in Graph 1.

DISCUSSION

Intimate contact between the RPD framework and abutment teeth was considered as areas where bare metal was exposed when PVS was being used to take the measurements. Numerous studies cite that a gap from 0 to 50 µm was considered intimate contact (no gap)[5,9]. Some studies have defined a clinically acceptable fit as gap within the range of 50 to 311μm[10]. Although none of the RPD frameworks in this study achieved intimate contact to the rest seats, direct observation of intimate contact (fit) between clasp assemblies of the RDP frameworks and the abutment teeth was made. According to a study by Lee, the accuracy observed at the periphery of rests was better than that of the center of the rest[11]. Dunham found that the majority of rests did not contact the rest seats[2]. However, overall, all the RDP frameworks in this study achieved clinically acceptable fit accuracy less than 311 μm (Table 2). In addition all of the RPD frameworks achieved retention, resistance and support in this study. It is interesting to note that there is not a universally agreed set of guidelines that deem a framework accurate and well-fitting in literature.

It is difficult for clinicians to control the gap spaces because they were created during the fitting and finishing of the RPD framework in the dental laboratory. Based on a study by Brudvik and Reimers, an average of 127 μm of metal is lost from the intaglio surface of Co-Cr RPD frameworks upon finishing and polishing[3]. During this study, the RPD frameworks from Group 1 and Group 2 needed further adjustments by the investigator prior to trying in. This means that the RPD frameworks that were fabricated from Group 3 (digital impressions) did not have to lose additional metal from chairside adjustment and they will ultimately save clinician's time of the RPD delivery. In addition, the Group 3 specimens did not require additional dental laboratory steps of boxing and pouring master casts. In addition, the STL files is permanent and available for future use if remaking of the RDP framework is necessary[5].

There are limitations in this study. Utilization of a digital caliper and bite registration material are common armamentarium in previous RPD fit studies[2,9]. However, the elasticity associated with the bite registration material coupled buy the high sensitivity of the caliper can make getting accurate measurements time consuming and difficult. In addition, the use of a resin model to evaluate the RPD frameworks does not account for resiliency of the supporting structures in the oral cavity.

CONCLUSION

Based on the findings in this study, the fit accuracy of a RPD framework was not affected by different dental impression materials; polyvinylsiloxane, alginate or digital impression. Utilizing proper techniques with any of these impression materials can yield clinically acceptable fitting RPD frameworks. However, the RPD frameworks that were made from digital impressions required no trying-in adjustment. Additionally, they did not require additional laboratory step and material. Further studies are recommended utilizing larger sample sizes and in vivo studies to achieve greater accuracy in results.

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Flow Diagram of Phases of this Study

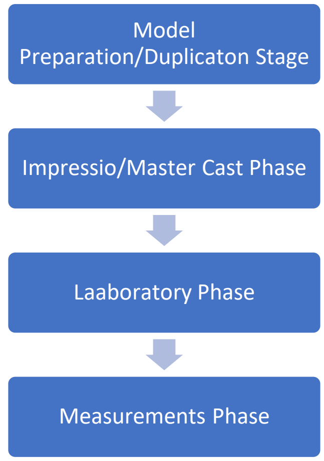
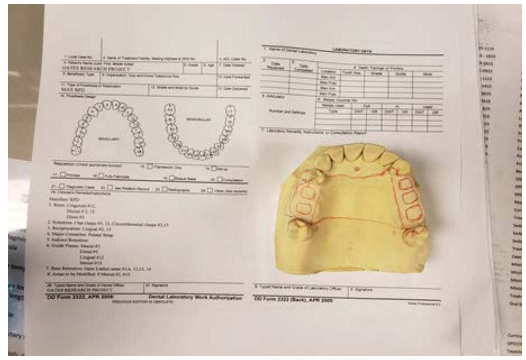


Figure 1.

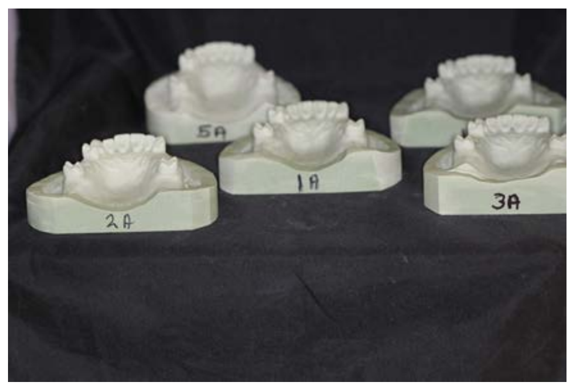
Typodont ready to be prepped
Figure 2

Typodont was surveyed and prepped
Figure 3



RPD framework prescription
Figure 4

3 identical models
Figure 5



10 impressions boxed, poured labeled for shipping to lab
Figure 6

5 individual scans were done on the Primescan Intraoral Scanner
Figure 7

15 RPD frameworks were inventoried labeled and inspected
Figure 8

A digital caliper was used to take all measurements
Figure 11

PVS was used to measure the gap space
Figure 12

Material	**Adjustments?: Y or N**	**Time Necessary for Adjustments**
ALGINATE		
A1	Y	10 min
A2	N	0 min
A3	N	0 min
A4	Y	5 min
A5	Y	10 min
PVS		
P1	N	0 min
P2	Y	2 min
P3	Y	5 min
P4	N	0 min
P5	N	0 min
STL FILES		
S1	N	0 min
S2	N	0 min
S3	N	0 min
S4	N	0 min
S5	N	0 min

Table 1

Measurements on 15 RPD Frameworks

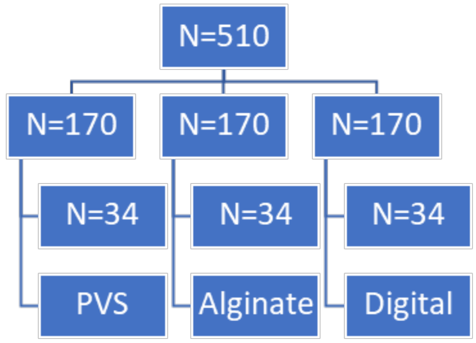


Figure 13

Measurements on the C clasp assemblies

Figure 9

Measurements for I-bar assemblies

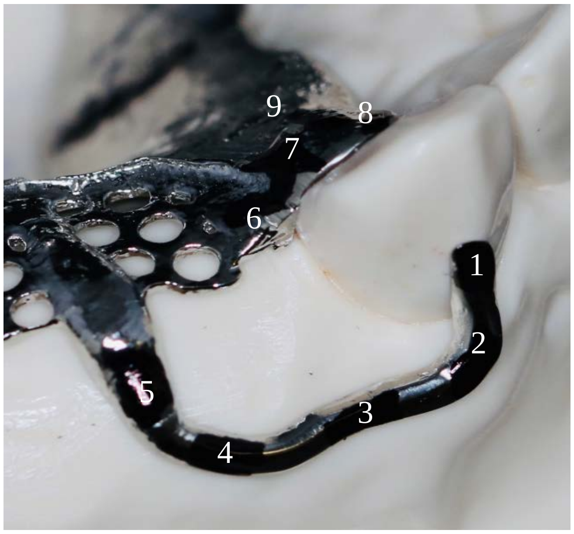
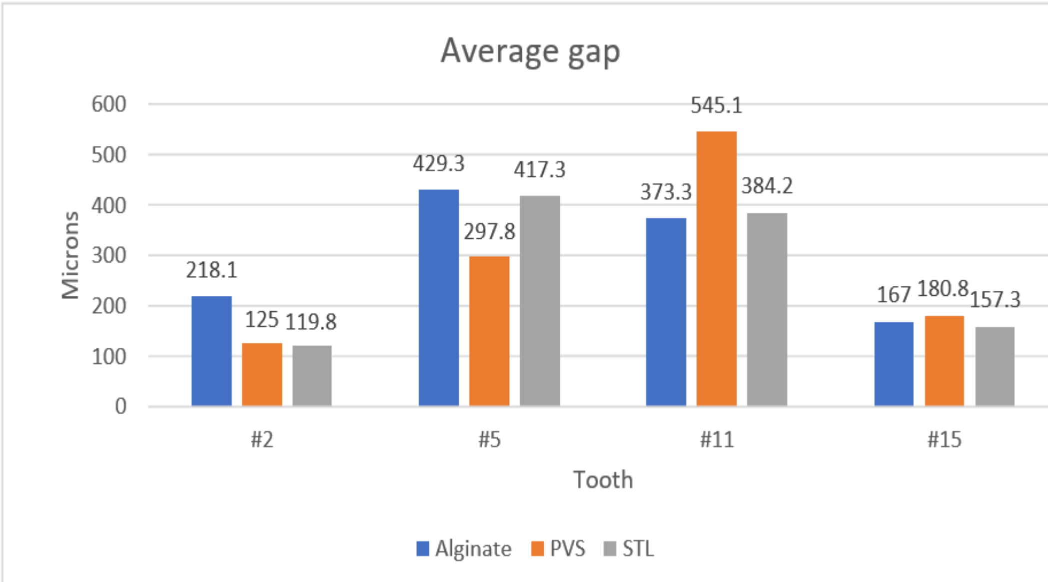


Figure 10

Gap Spaces by Material



Graph 1

Gap Spaces by Material

	Group 1	**Group 2**	**Group 3**
Impression material	296.9 µm	287.2 µm	269.6 µm
Rest Seat	267 µm	256 µm	272 µm

Table 2

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