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# Linear Dimensional Change and Accuracy of Fit of Positive Pressure Thermo–Formed Prosthodontic Materials

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**الخلاصة**

**الاهداف:**تهدف الدراسة **إلى** تحديد دقة وثباتية الحجوم لقواعد التعويضات السنية المشكلة حراريا. **المواد وطرائق البحث :** استخدمت ستة أنواع مختلفة من المواد المشكلة حراريا. وتم حساب التغييرات الطولية عن طريق قياس محيط المثلث المتكون بين ثلاث نقاط مثبتة على قالب قياسي معدني يمثل الفك العلوي الادرد. كما تم قياس التغييرات في الثباتية عن طريق حساب الفراغ المتكون بين القالب والمادة المشكلة حراريا. وفي كلا الحالتين تم استعمال قمرة رقمية فائقة الوضوح وبرنامج تصميم حاسوبي متطور. وتمت الحسابات بعد مرور( يوم واحد، ويومين، وثلاثة، وأخيرا سبعة أيام) بعد عمل العينات.واستخدمت البرامج الإحصائية :تحليل التباين واختبار دنكن لتحليل البيانات . **النتائج:**كانت نتائج التغييرات الطولية مؤثرة معنويا لكل المواد. كان التغير الحاصل بعد( سبعة ايام) غير مختلف معنويا عن التغيير الحاصل بعد اليوم الاول. **الاستنتاجات:** أظهرت جميع المواد المشكلة حراريا تغييرا حجميا. وكانت اكثر المواد استقرارا من الماد الصلبة هي (ديوران) وأكثر المواد استقرارا من المواد المرنة هي (ديوراسوفت).

**ABSTRACT**

**Aims:** To determine the dimensional accuracy of thermoformed dental base plates. **Materials and methods**: Six different types of thermoformed materials were used. The circumference of the triangle formed between the index marks on standard maxillary edentulous metal model and measurements of the surface area of the gap between the posterior margin of base plate and the metal model were captured with digital camera and measured with AutoCAD program. Measurements were made after 1 day after processing and then 2, 3 and 7 days. ANOVA and Duncan multiple range test were used to statistical analysis of the data. **Results**: The linear dimensional shrinkage and inaccuracy of fitness were significant for all of the thermoformed materials. The change after 7 days was not significantly different from that occurred after 1 day. **Conclusions**: All thermoformed materials exhibited dimensional instability, the Duran(hard material) and Durasoft(flexible material) were the most dimensionally stable and accurately fitted thermoformed materials.

**Key words:** dimensional accuracy**,** thermoformed material**.**

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## INTRODUCTION

Vacuum thermoforming is a plastic thermoforming process that involves forming thermoplastic sheets into three–dimensional shapes through the application of heat and pressure. Basically during vacuum forming processes, plastic material is heated until it becomes pliable, and then it is placed over a mold and drawn in by a vacuum until it takes on the desired shape. Vacuum thermoforming is a huge method for producing plastic parts that has sharp details and fit nicely to specific products. The greatest advantages of vacuum forming are the ease of handling, constant heating temperature regardless to the external influence and power supply, short working time and less parts and therefore more cost effectiveness. [1,2]

Thermoforming process has been used to produce a variety of dental prostheses that include splints, stents, mold duplication, mouth guards, implant positioners, occlusal splints, record bases and else.(1–7) Previous studies characterized thermoformed materials with respect to molecular weight, residual monomer contents, glass transition temperature and wear resistance.(7,8)

A prerequisite of stable denture is the accurate recording of the relationship between the upper and lower jaws through a stable occlusal rim and trial denture which should fit the cast and the mouth accurately(9), it is therefore important that the thermoformed material also accurately fit the cast to which it was adapted and maintain its shape and integrity, therefore the investigations that done to report the dimensional accuracy and the accuracy of adaptation of the thermoformed material to the dental casts are very important.(10–14)

## MATERIALS AND METHODS

Six different types of hard and flexible thermoformed materials are selected for characterization. The hard materials include: Imprelon, Biocryl C, and Duran. The flexible thermoformed materials include: Bioplast, Durasoft and Coplast. All of these materials are produced by Scheu/Dental (Iserlohn, Germany).The imperelon is hard elastic foil,bonds easily to acrylic. Biocryle C is pure acrylic material with no monemer residues.Duran is hard elastic transparent foil,bonds to acrylic.Bioplast is flexible material that dosenot bond to acrylic.Durasoft is sandwich foil material . Coplast is tough elastic foil that dosenot bond to acrylic (Manufacturer). A metal model resemble the maxillary edentulous alveolar ridge with 3 reference marks were used for this research, one of the marks was found on the anterior region near the incisive papilla, the other two marks were positioned on the right and the left 2nd premolar region (Figure 1).

Figure (1):Metal model with reference points

The using of metal mold to measure the dimensional accuracy of the material was documented by many researchers.(15-18) Biostar thermoforming equipment (Scheu dental Am Burgerg, Germany) (Figure 2) was used in the fabrication of the specimens.


Figure (2): Biostar thermoforming equipment

The thermoforming equipment consists of infrared heater, forming table, clamping frame and reservoir for air pressure supply. During the forming stage the metal model was positioned on the forming table, the thermoplastic sheet was positioned in the clamping ring above the metal model and below the heating element. The power and the heating circuit were switch on, after setting the code, the infrared heater reach the working temperature and the thermoformed sheet can be plasticized. Eight specimens were prepared for each type. A digital camera (Sony, Japan) with a very high degree of resolution was used and placed at constant distance (30cm) away from each specimen using stable horizontal stand. For the linear dimensional change the distance between the 3 index marks were measured and collected to produce the circumference of ABC triangle (Figure 3).

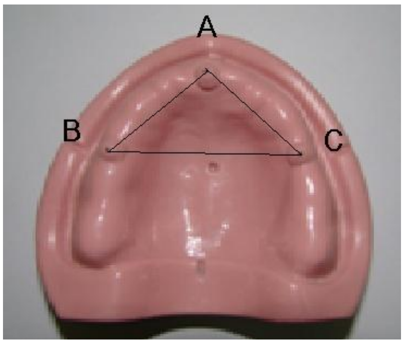



Figure (3):specimen for liner dimensional change

The predetermined distance were measured in graph using the AutoCAD computerized program with (00.0000 mm) degree of accuracy after 1,2,3 and 7 days. For the accuracy of adaptation test, the area of the space occurred between the posterior border of the specimen and the posterior margin of the metal model were recorded and measured (Figure 4). [19]

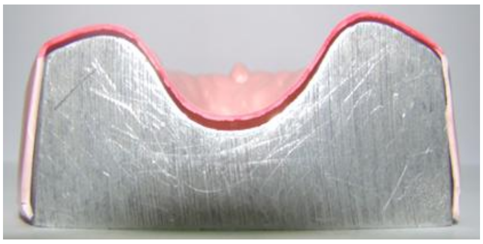


Figure (4):specimen for accuracy of fit

## RESULTS

The linear dimensional change of the thermoformed materials after 1,2,3 and 7 days were calculated (Tables 1–6, Figures 5–10), each figure presents the measurements of the circumference of ABC triangle that formed on the metal model and on the thermoformed base plate after 1,2,3 and 7 days after processing. All results showed significant shrinkage of the linear measurements of the thermoformed materials from that on the metal model. For the Imprelon thermoformed material, the linear dimensional change was highly significant (Table 1).

Table (1): ANOVA for linear dimensional change of Imprelon material.

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 32.358 | 4 | 8.089 | 36.498 | .000 |
| **Within Groups** | 7.757 | 35 | .222 | | |
| **Total** | 40.115 | 39 | | | |

Duncan multiple range test indicated that the shrinkage that occur after and 7 days (87.6776 mm) was greater but not significant from the measurements after 1 day (87.7357mm) (Figure 5).

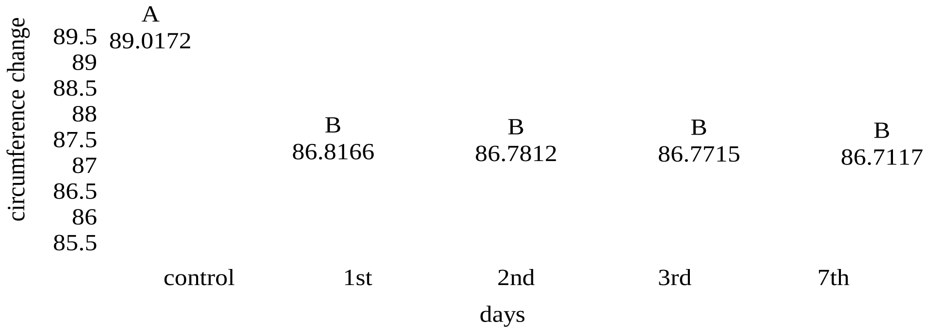



Figure (5): Duncan for linear dimensional change of Imprelon material.

The same results were obtained with the Biocryle C and Duran thermoformed materials (Tables 2,3 and Figures 6,7).

Table (2): ANOVA for linear dimensional change of Biocryl C material.

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 41.277 | 4 | 10.319 | 31.450 | .000 |
| **Within Groups** | 11.484 | 35 | .328 | | |
| **Total** | 52.761 | 39 | | | |

Table (3): ANOVA for linear dimensional change of Duran material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 11.110 | 4 | 2.778 | 28.753 | .000 |
| **Within Groups** | 3.381 | 35 | .097 | | |
| **Total** | 14.491 | 39 | | | |

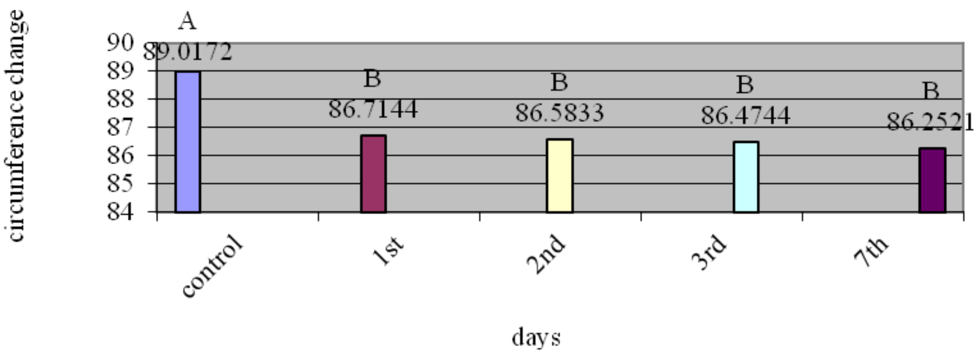



Figure (6): Duncan for linear dimensional change of Biocryl C material

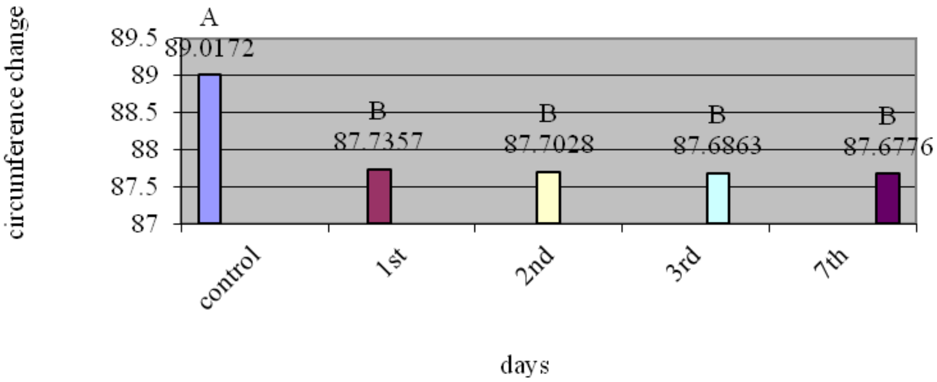



Figure (7): Duncan for linear dimensional change of Duran material

The linear shrinkage for the Biocryle C after 1 and 7 days was (86.7144mm and 86.2521 mm) successively and (87.7357 mm and 87.6776 mm) for Duran thermoformed material. For the Bioplast flexible thermoformed materials, ANOVA test indicated that there was significant linear dimensional shrinkage of the thermoformed base plate after different periods (Table 4, Figure 8) and the shrinkage that occurred after 7 days was significantly greater than that occurred after 1 day.

Table (4): ANOVA for linear dimensional change of Bioplast material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 68.849 | 4 | 17.212 | 55.520 | .000 |
| **Within Groups** | 10.851 | 35 | .310 | | |
| **Total** | 79.700 | 39 | | | |

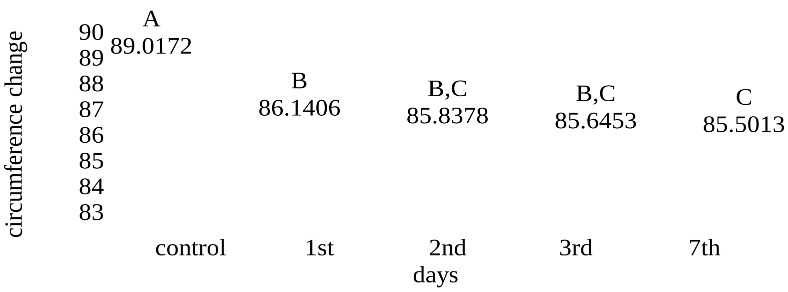



Figure (8): Duncan for linear dimensional change of Bioplast material

The Linear dimensional shrinkage of the Durasoft and Coplast thermoformed material was also significant but the change after 7 days was not significantly greater than that occurred after 1 day (Tables 5,6 and Figures 9,10), the same as that of the hard thermoformed materials.

Table (5): ANOVA for linear dimensional change of Durasoft material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 5.815 | 4 | 1.454 | 4.544 | .005 |
| **Within Groups** | 11.197 | 35 | .320 | | |
| **Total** | 17.012 | 39 | | | |

Table (6): ANOVA for linear dimensional change of Coplast material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 42.741 | 4 | 10.685 | 288.220 | .000 |
| **Within Groups** | 1.298 | 35 | .037 | | |
| **Total** | 44.038 | 39 | | | |

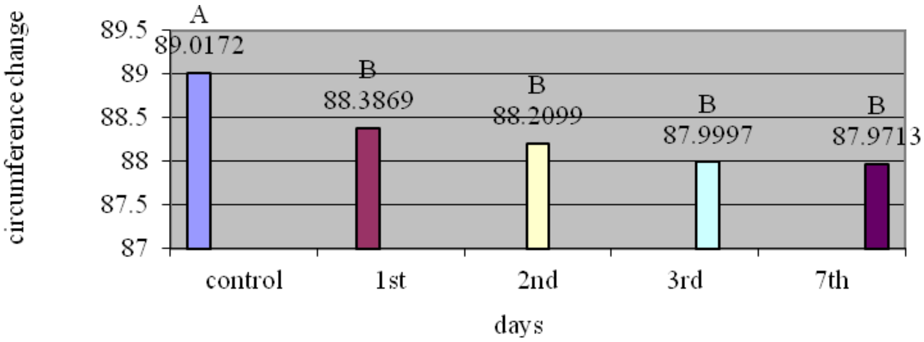



Figure (9): Duncan for linear dimensional change of Durasoft material

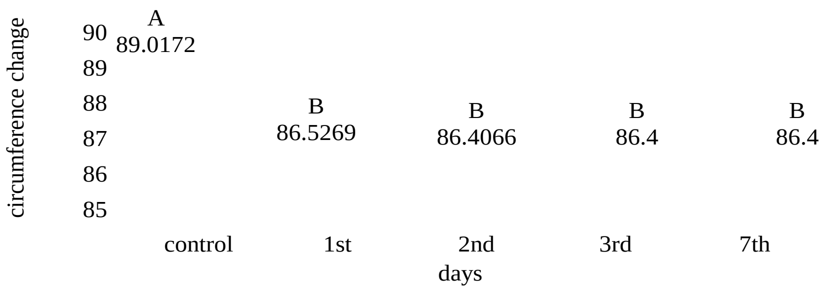



Figure (10): Duncan for linear dimensional change of Coplast material

ANOVA and Duncan multiple range test were applied to select the materials that exhibit greater significant shrinkage (Tables 7,8 and Figures 11,12).

Table (7): ANOVA for linear dimensional change among hard thermoformed materials.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 8.469 | 2 | 4.235 | 16.732 | .000 |
| **Within Groups** | 5.315 | 21 | .253 | | |
| **Total** | 13.784 | 23 | | | |

Table (8): ANOVA for linear dimensional change among flexible thermoformed materials.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 24.985 | 2 | 12.492 | 90.789 | .000 |
| **Within Groups** | 2.890 | 21 | .138 | | |
| **Total** | 27.874 | 23 | | | |

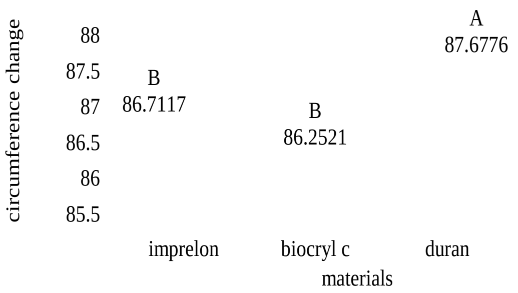



Figure (11): Duncan for linear dimensional change among hard thermoformed materials

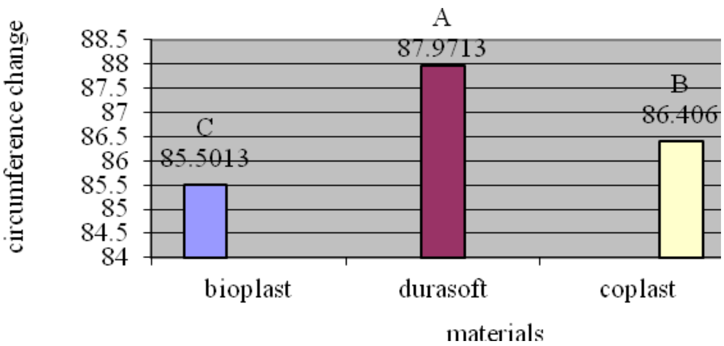



Figure (12): Duncan for linear dimensional change among flexible thermoformed materials.

For the hard thermoformed materials, Duran showed the significant dimensional shrinkage (87.6776mm) as compared with the metal model (89.0172mm), while for the flexible thermoformed materials, Durasoft exhibited the significant change (87.9713mm) followed by Coplast and Bioplast materials. The accuracy of fitness of the thermoformed materials was studied (Tables 9–15, Figures 13–18). All of the materials present the production of significant gap at the posterior palatal border. For the Imprelon and Biocryle C, this gap was significant at the 7$^{th}$ day than that formed at the 1$^{st}$ day (Tables 9,10 and Figures 13,14).

Table (9): ANOVA for accuracy of fit of Imprelon material.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 7332.420 | 4 | 1833.105 | 53.981 | .000 |
| **Within Groups** | 1188.533 | 35 | 33.958 | | |
| **Total** | 8520.953 | 39 | | | |

Table (10): ANOVA for accuracy of fit of Biocryl C material

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 10000.231 | 4 | 2500.058 | 283.813 | .000 |
| **Within Groups** | 308.309 | 35 | 8.809 | | |
| **Total** | 10308.541 | 39 | | | |

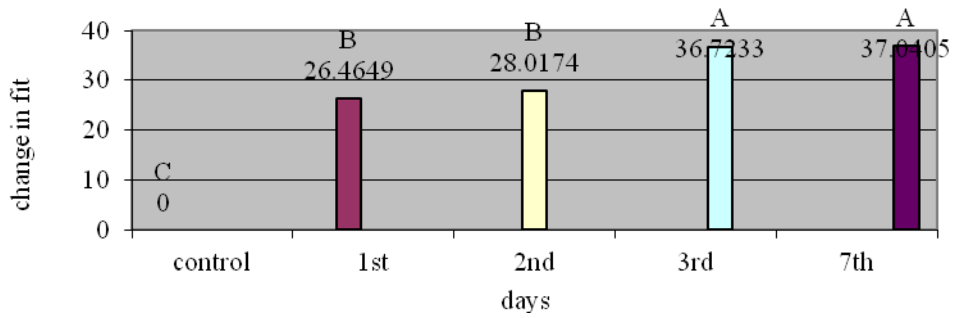



Figure (13): Duncan for accuracy of fit of Imprelon material

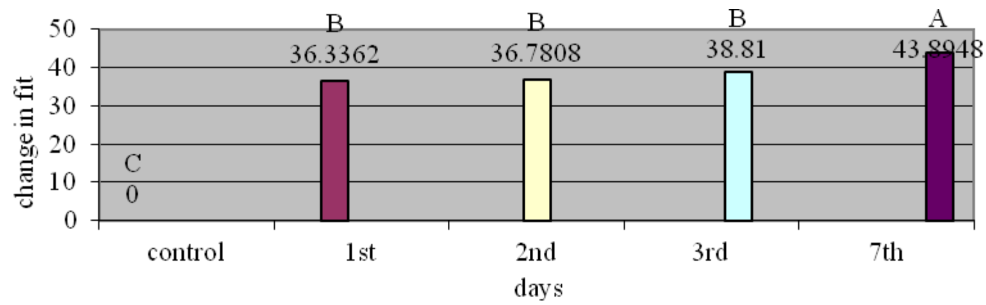



Figure (14): Duncan for accuracy of fit of Biocryl C material

For the Duran material, there was no significant difference between the 1st and 7th days (Table 11, Figure 15).

Table (11): ANOVA for accuracy of fit of Duran material.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 1578.103 | 4 | 394.526 | 16.701 | .000 |
| **Within Groups** | 826.777 | 35 | 23.622 | | |
| **Total** | 2404.880 | 39 | | | |

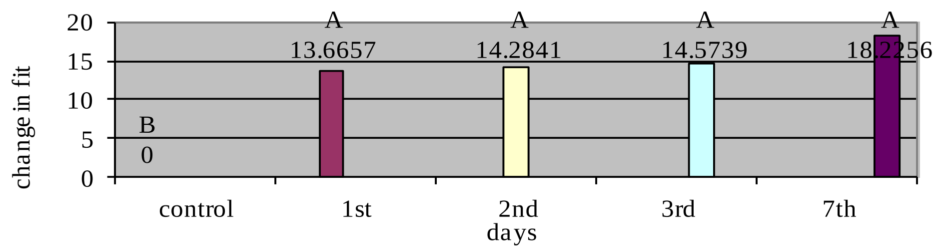



Figure (15):Duncan for accuracy of fit of Duran material

And the same results were obtained with all flexible thermoformed materials (Tables 12–14, Figures 16–18).

Table (12): ANOVA for accuracy of fit of Bioplast material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 20234.859 | 4 | 5058.715 | 80.456 | .000 |
| **Within Groups** | 2200.648 | 35 | 62.876 | | |
| **Total** | 22435.507 | 39 | | | |

Table (13): ANOVA for accuracy of fit of Durasoft material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 7160.551 | 4 | 1790.138 | 163.239 | .000 |
| **Within Groups** | 383.822 | 35 | 10.966 | | |
| **Total** | 7544.373 | 39 | | | |

Table (14): ANOVA for accuracy of fit of Coplast material

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 63154.855 | 4 | 15788.714 | 253.610 | .000 |
| **Within Groups** | 2178.959 | 35 | 62.256 | | |
| **Total** | 65333.814 | 39 | | | |

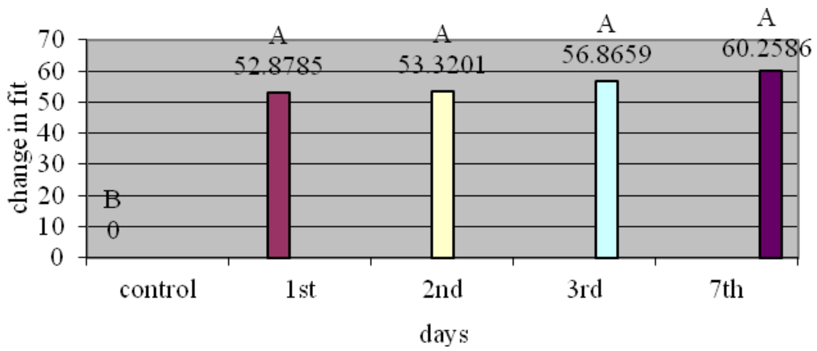



Figure (16):Duncan for accuracy of fit of Bioplast material

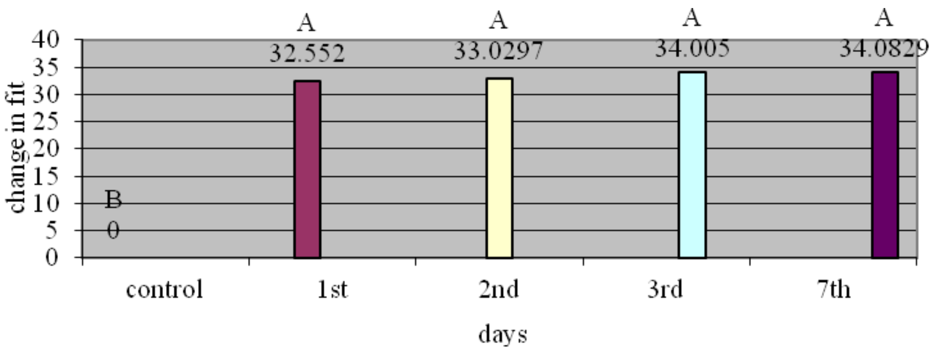
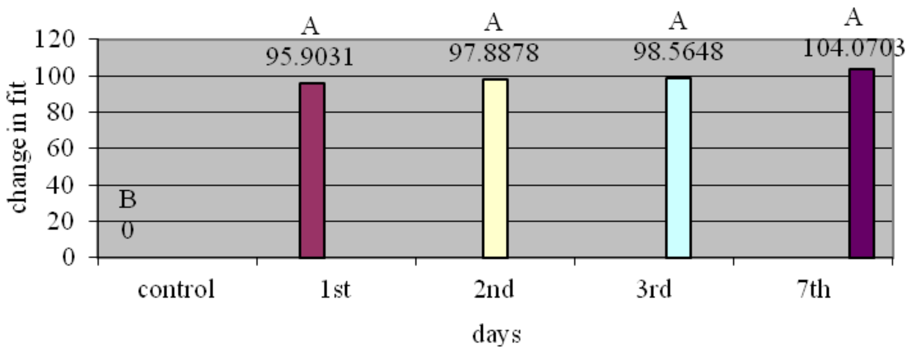



Figure (17):Duncan for accuracy of fit of Durasoft material




Figure(18): Duncan for accuracy of fit of Coplast material

ANOVA and Duncan multiple range test showed that the Duran thermoformed material showed the significant adaptation to the metal model ($18.2256mm^2$) as compared to other hard thermoformed materials and the Durasoft ($34.0829\ mm^2$) when compared to other flexible thermoformed materials (Tables15,16 and Figures 19,20).

Table(15): ANOVA for accuracy of fit among hard thermoformed materials

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 2826.363 | 2 | 1413.181 | 24.439 | .000 |
| **Within Groups** | 1214.313 | 21 | 57.824 | | |
| **Total** | 4040.676 | 23 | | | |

Table(16): ANOVA for accuracy of fit among flexible thermoformed materials

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 20007.662 | 2 | 10003.831 | 171.440 | .000 |
| **Within Groups** | 1225.386 | 21 | 58.352 | | |
| **Total** | 21233.048 | 23 | | | |

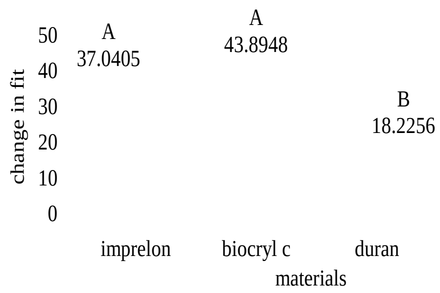



Figure (19): Duncan for accuracy of fit among hard thermoformed materials.

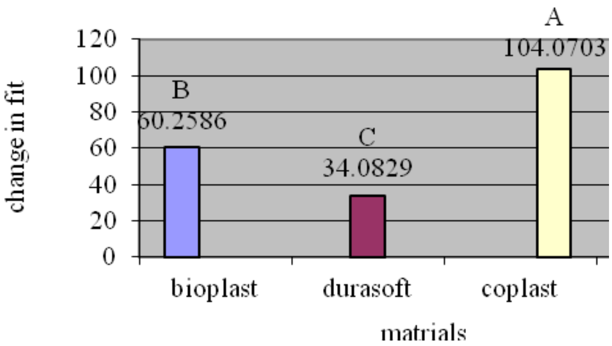



Figure (20): Duncan for accuracy of fit among flexible thermoformed materials

## DISSCUTION

In this research, it was noticed that thermoformed materials exhibit significant linear dimensional shrinkage (Tables 1–6). The stretching of thermoformed materials was the result of current construction process that used dedicated dental thermo-forming instrument employing vacuum and air pressure to maximize adaptation accurately. This was documented by other researchers. [10,13] The stretching of maxillary base plate lead to the development of significant space at the posterior palatal border (Tables 9–15). The development of space between the posterior palatal region of the metal model and the base plate was explained in terms of strain release in the maxillary base plate which causes stretching of maxillary denture base. This stretching has a tendency to draw the flange inward with resultant elevation of the palate.[20,21]

Generally the linear dimensional shrinkage of the thermoformed material after 7 days was not significantly greater than that occurred after one day, this encourage the explanation that, the main cause for the dimensional inaccuracy was the current construction process that involves using vacuum and air pressure to maximize the adaptation. Jagger *et al*. 2003 demonstrated that there was no significant difference in the accuracy of adaptation of the thermoformed materials over time. This result was also documented in this research as the adaptation of the thermoformed material generally not significantly changed after 7 days from that obtained after 1 day except the Imprelon and Biocryl C materials (Figures 13–14).

The result obtained in this research demonstrated that the most dimensional stable and accurately fitted thermoformed material was the Duran as compared to other hard thermoformed materials (Figures 11,19) and the Durasoft when compared to other flexible thermoformed materials (Figures 12,20).

## CONCLUSIONS

1. Thermoformed materials exhibit linear dimensional shrinkage and change in fitness after processing, this was due to the using of the vacuum and air pressure during the construction process.
2. Because of the current construction process, the linear dimensional shrinkage and the change of fitness for the most of the thermoformed materials that occur after 7 days were not different from that occurred after the first day.
3. In relation to the hard thermoformed material, Duran was the most dimensionally stable and accurately fitted.
4. The Durasoft was the best flexible thermoformed material in regard to dimensional stability and accuracy of fitness.

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