Appraisal of Dimensional Accuracy in Five Brands of Extended Pour Irreversible Hydrocolloid Materials for FDP Impression

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Abstract

Aim. The purpose of this study was to assess and compare the dimensional accuracies of five brands of extended pour irreversible hydrocolloid materials for fixed dental prosthesis impression.

Materials and methods. Impressions of a master stainless steel model were made with five extended pour irreversible hydrocolloids and one addition silicone impression material. A total of ninety impressions (n=90) were made, with fifteen for each group of impression material. The stone dies retrieved from these impressions were analysed with Baty-Vision Systems - Venture 3D CNC machine, for dimensional accuracies. Comparison of continuous data between two groups was done with the Wilcoxon rank-sum test (Mann Whitney U test) and for more than two groups with the Kruskal Wallis test ($\alpha = .05$)

Results. All six impression materials showed some amount of error. On comparison of the median total absolute deviation of the various dimension of stone dies, the accuracies of impression materials in decreasing order appeared to be Neocolloid >> Affinis >> Coltoprint >> Zelgan >> 3M ESPE >> Plastalgin. On the contrary, a comparison of the impression materials, in terms of several dimensions of stone dies differing significantly from the stainless-steel model, the sequence in terms of accuracy was, Coltoprint > Affinis >3M ESPE > Neocolloid > Plastalgin > Zelgan.

Conclusions. Based on the dimensional accuracies of the stone dies retrieved from the impressions, Neocolloid was found to be the best impression material with the least possible deviation, followed by Coltoprint and Affinis.

***Keywords**: Extended pour irreversible hydrocolloid; Dimensional accuracy; FDP*

Introduction

Dimensional accuracy of impression is as critical as the working cast, for precise fit and success of fixed dental prosthesis.[1-3] This warrants the use of the right choice of impression material.[4,5] Addition silicone has been the material of choice for a fixed dental prosthesis (FDP) until now.[6] Along with dimensional accuracy, it has good detail reproducibility, ease of handling, and superb elastic recovery. Even multiple casts can be poured from a single impression.[7,8] Nevertheless, the material is quite expensive, and the technique sensitive in nature.[9] Being intrinsically hydrophobic, it requires an extrinsic surfactant to avoid voids formation, at the margin of tooth preparation.[10] This necessitated the development of cheaper impression material, with dimensional accuracy similar to addition silicone.[11]

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A substitute to addition silicone can be irreversible hydrocolloid, owing to its ease of manipulation and cost-effectiveness.[12] Nevertheless, the irreversible hydrocolloid impression has low dimensional stability and needs to be poured immediately.[13, 15] Again, it has a low tear strength, tendency to stick to teeth with poor adhesion to the tray. So, the use of this material was initially restricted for the diagnostic cast.[15] But, the new generation of extended-pour irreversible hydrocolloids has extended pour time, colour-changing nature, high viscosity, and dust-free properties with better adherence to a tray.[16-18] So, the dimensional accuracy of these new generation irreversible hydrocolloids, need to be assessed and compared with addition silicone impression material for FDP impression.[19]

Dimensional accuracy of the impression is either assessed directly or indirectly on the stone cast, retrieved from the impression.[19] Literature shows the use of image analyser, coordinate measuring machine (CMM) Carl Zeiss Contura G 2, travelling microscope (ELFO, India Pvt. Ltd), micrometres, and digital modelling, for the dimensional measurement.[15, 20,21] Baty Vision Systems - Venture 3D CNC is a new machine in this category. The upgraded fusion software of this machine, inspects the model completely automatically, thereby making the scanning and best fitting process quick. Once the parts are measured, a full CNC program is generated automatically. This saves the time of skilled operators. Moreover, the procedure of CNC programming is easy to learn and repeat.

The present study was designed to assess and compare the dimensional accuracies of five brands of extended-pour irreversible hydrocolloid materials for fixed dental prosthesis impression. The null hypothesis stated that all the five brands of extended pour irreversible hydrocolloids and addition silicone impression material were similar, in terms of dimensional accuracy of impressions and therefore the generated casts.

Material and Methods

Six impression materials, with five brands of extended-pour irreversible hydrocolloids and one addition silicone impression material, was assessed in this study, for dimensional accuracy (Table 1). All the measurements were done indirectly on the stone dies retrieved from the impressions.[22]

The clinical situation for the fabrication of FDP was simulated with a master stainless steel model (Fig 1A). This model was having two prepared abutments (A, B) with six-degree occlusal convergence, the gingival finish line with 1mm width, and a ninety-degree shoulder.[23] Cross grooves were inscribed on the occlusal and proximal surfaces of these abutments for reference measurement. For proper orientation of the impression tray, a step was present on the base of the stainless-steel model.[23] The entire master model was designed with SOLID WORKS® software and was milled in high precision AGNI+ BMV 45+ TC24 milling machine, in accordance to the ANSI/ADA stipulations (8.015mm in height, 6.330mm diameter at the apex and 8.450mm diameter at the base of the abutment, with a 28.270 mm inter-abutment distance).[24, 25] Descriptions of all the nine locations of the stainless-steel model used for measurements are given in the schematic form (Fig 1B). This model provided a good baseline condition for comparisons of impression materials.

A single customized stainless-steel perforated tray, with metallic handle, was used throughout the study, to standardize impression making. The perforations were of 2mm diameter for the mechanical retention and were designed to hold the 4mm thickness of impression material (Fig 1A).[26]

All the six impression materials were manipulated in standard proportions as per the manufacturer's instruction, at room temperature (25±2℃). The irreversible hydrocolloids were mixed manually, with a clean rubber bowl and spatula, whereas a one-step double mix impression technique was used for the addition of silicone impression material. Care was taken to apply a thin layer of tray adhesive (VPS Tray Adhesive; 3M ESPE) to the intaglio surface of the tray, before loading of the addition silicone. To make the impression the loaded impression tray was pressed over the master stainless steel model. At that juncture, the whole assembly was submerged in a water bath having a temperature of 35°C±1°C, till the material set.[27] This mimicked the oral environment. The temperature of the water bath was regulated with a mercury thermometer.

A total of ninety impressions (n=90) of the master stainless steel model were made for six groups, with fifteen for each group of impression material. Following the set, impressions were detached from the stainless model in a snap movement, parallel to the long axis of prepared abutments. The unsatisfactory impressions with voids and inaccuracies were discarded from the study. To simulate the clinical procedure, the approved impressions were air-dried and preserved in sealed plastic bags (100% relative humidity) at room temperature for half an hour.[28]

Type IV dental stones (Kalrock: Kalabhai Karson Pvt., Ltd, and Pearlstone: Asian chemicals) were used to pour the impressions. They were vacuum mixed (Multivac 4; Degussa), under standardized conditions, as per manufacturer's instructions, and vibrated (EWL 5403; KaVo EWL) into the impressions. After setting, stone dies were separated from impressions and ready for measurement.

Measurements of the stone dies were done with Baty Vision Systems - Venture 3D CNC machine supported by fusion software. This machine has a high-resolution 0.5μm scale for increased accuracy. For measurement, stone dies (n=90) were mounted on the jig of Baty Vision systems, to orient the occlusal surfaces of the abutments in the horizontal plane. Before this master stainless steel model was calibrated in the Baty Vision Systems - Venture 3D CNC machine. Measurements were made for abutment diameters (A- m1, m2, m3 and B- m5, m6, m7), height (A-m4, B-m8), and the inter-abutment distance between abutment A and B (m9). The obtained results were tabulated for statistical analysis.

Statistical Analysis

Measurements of all the nine locations, of the stainless-steel master model, as well as stone, dies (n=90 @ 15 per group) for six impression groups were tabulated and statistically analyzed using the software STATA 12.1. Descriptive statistics in the form of mean and standard errors were computed. Since the sample size was small, non-parametric tests were used for testing the hypothesis of a significant difference. A comparison of continuous data between two groups was done with the Wilcoxon rank-sum test (Mann Whitney U test) and for more than two groups with the Kruskal Wallis test. Cut of significant probability was tested at $\alpha = .05$, whereas highly significant values were tested at $\alpha = .01$ levels.

Results

The comparison of the nine dimensions of master stainless steel model with that of stone dies, retrieved from six categories of impression materials, are displayed in tabular form (Table 2). They are presented in the form of the absolute mean values, corresponding standard deviation, and P-value, of the nine dimensions of stone casts belonging to six groups.

According to the Table, all the six groups of impression materials were still found to have an error, for the abutment diameter (A- m1, m2, m3 and B- m5, m6, m7) and height (A-m4, B-m8). However, the inter-abutment distance between abutment A and B (m9) was not found to be significantly different, for any of the six impression groups.

On comparison of the median total absolute deviation of the various dimension of stone dies (m1, m2, m3, m4, m5, m6, m7, m8, m9) using Kruskal Wallis Test, a significant difference ($p = .0041$) was found between the groups (Table 3, Fig. 2). Groups having significant differences were further compared with each other using the Man-Whitney Test. It was seen that Neocolloid was having a significant difference with Plastalgin, 3M ESPE, and Zelgan, while Plastalgin was having a significant difference with Zelgan, Affinis, and Coltoprint ($\alpha = .05$). No other groups were found to have a significant difference. It appeared that the accuracy of impression materials in decreasing order are Neocolloid >> Affinis >> Coltoprint >> Zelgan >> 3M ESPE >> Plastalgin.

On the contrary, a comparison of the impression materials, in terms of numbers of dimensions of stone dies differing significantly from the stainless-steel model, a different outcome was found (Fig.3). As per the Figure, Coltoprint was found to be the best material, with the least number of dimensions differing from the stainless-steel model. Affinis followed next in order. So, the sequence in terms of accuracy were, Coltoprint > Affinis >3M ESPE > Neocolloid > Plastalgin > Zelgan

Table 1 Description of the impression materials

Type of impression materials	Trade name	Manufacturer
Irreversible hydrocolloid	Neocolloid	Zhermack
	Plastalgin	Septodont
	3M ESPE	3M
	Zelgan	Dentsply
	Coltoprint	Coltene
Addition silicon	Affinis	Coltene

Table 2 Comparisons of Dimensional accuracy of stone dies obtained from six impression material with master stainless steel model using Wilcoxon Signed rank test (n=15 for each group)

Dime-nsion	Master stainless steel model	IRREVERSIBLE HYDROCOLLOID										ADDITIONAL SILICONE	
		Neocolloid		Plastalgin		3M ESPE		Zelgan		Coltoprint		Affinis	
		Mean ± SE	P VAL	Mean ± SE	P VAL	Mean ± SE	P VAL	Mean ± SE	P VAL	Mean ± SE	P VAL	Mean ± SE	P VAL
M1	6.366	6.35±0.01	0.087	6.44±0.03	0.125	6.41±0.03	0.255	6.41±0.03	0.255	6.38±0.02	0.820	6.372±0.007	0.4225
M2	9.842	9.54±0.04**	0.001**	9.41±0.05**	0.001**	9.52±0.03**	0.001**	9.42±0.05**	0.001**	9.56±0.03**	0.001**	9.496±0.019**	0.0006**
M3	7.100	7.15±0.01**	0.002**	7.05±0.05	0.443	7.13±0.03*	0.028	7.10±0.04	0.306	7.15±0.03	0.053	7.153±0.024*	0.0466
M4	6.990	7.07±0.02**	0.004**	7.18±0.08**	0.006**	7.24±0.1**	0.001**	7.08±0.03**	0.002**	7.00±0.02	0.741	7.015±0.015	0.1671
M5	6.369	6.37±0.01	0.955	6.47±0.05*	0.014	6.37±0.01	0.459	6.42±0.02*	0.047	6.41±0.03	0.211	6.373±0.029	0.4257
M6	7.109	7.12±0.01	0.733	7.03±0.06	0.233	7.13±0.01	0.155	7.05±0.05	0.733	7.15±0.03	0.255	7.183±0.042*	0.0404
M7	9.502	9.49±0.01	0.394	9.35±0.08*	0.026	9.49±0.01	0.532	9.36±0.06**	0.003**	9.52±0.02	0.363	9.477±0.021	0.3626
M8	6.990	7.04±0.02*	0.020	7.1±0.06*	0.027	7.15±0.07*	0.029	7.06±0.02**	0.001**	7.02±0.02*	0.088	7.077±0.033*	0.0306
M9	20.273	28.26±0.01	0.334	28.24±0.05	0.495	28.26±0.02	0.649	28.21±0.04	0.191	28.32±0.03	0.231	28.283±0.033	0.5699

N.B: * Significant at 0.05 level, ** Significant at 0.01 level of significance.

Table 3: Median total absolute deviation of the stone dies using six impression materials (n=15 for each group)

Group	Median total absolute deviation#	25th percentile Q1	75th percentile Q3	Rank sum	'p' value Kruskal Wallis test
Neocolloid	7.339	5.943	10.506	391.5	0.0041
Plastalgin	14.771	9.634	24.992	971.0	
3M ESPE	10.506	8.281	15.257	755.0	
Zelgan	9.301	7.615	14.004	690.5	
Coltoprint	9.882	7.409	13.389	644.5	
Affinis	9.529	7.301	13.897	642.5	

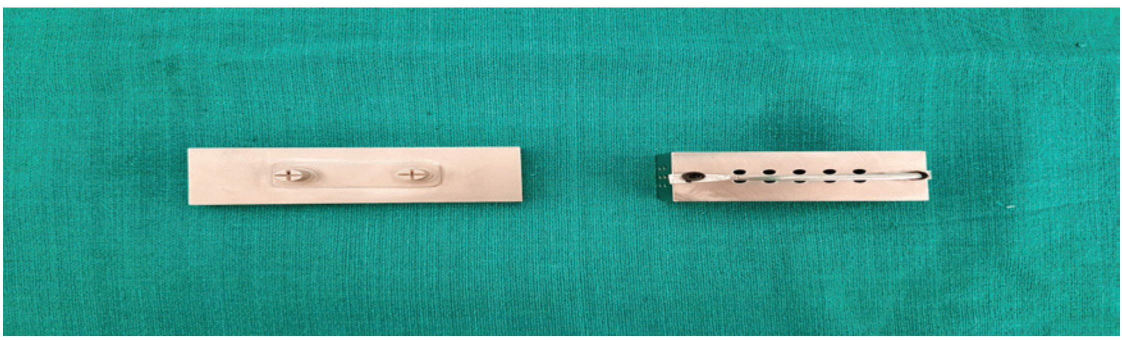
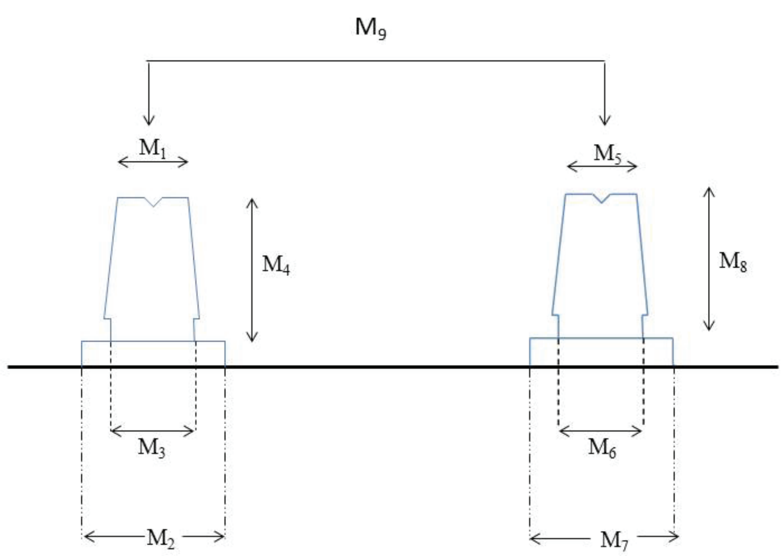


Figure 1A: Master stainless steel model with a custom tray



M_1 - Occlusal diameter of Abutment A(6.366). M_2 - Cervical diameter of Abutment A(9.842). M_3 - Diameter of undercut of Abutment A(7.100). M_4 - Occlusal-Gingival diameter of Abutment A(6.999). M_5 - Occlusal diameter of Abutment B(6.396). M_6 - Cervical diameter of Abutment B(7.109). M_7 - Diameter of undercut of Abutment B(9.502). M_8 - Occlusal-Gingival diameter of Abutment B(6.990). M_9 - Distance between Abutment A and Abutment B(28.273).

Figure 1B: Schematic diagram of nine dimensions of the master stainless model

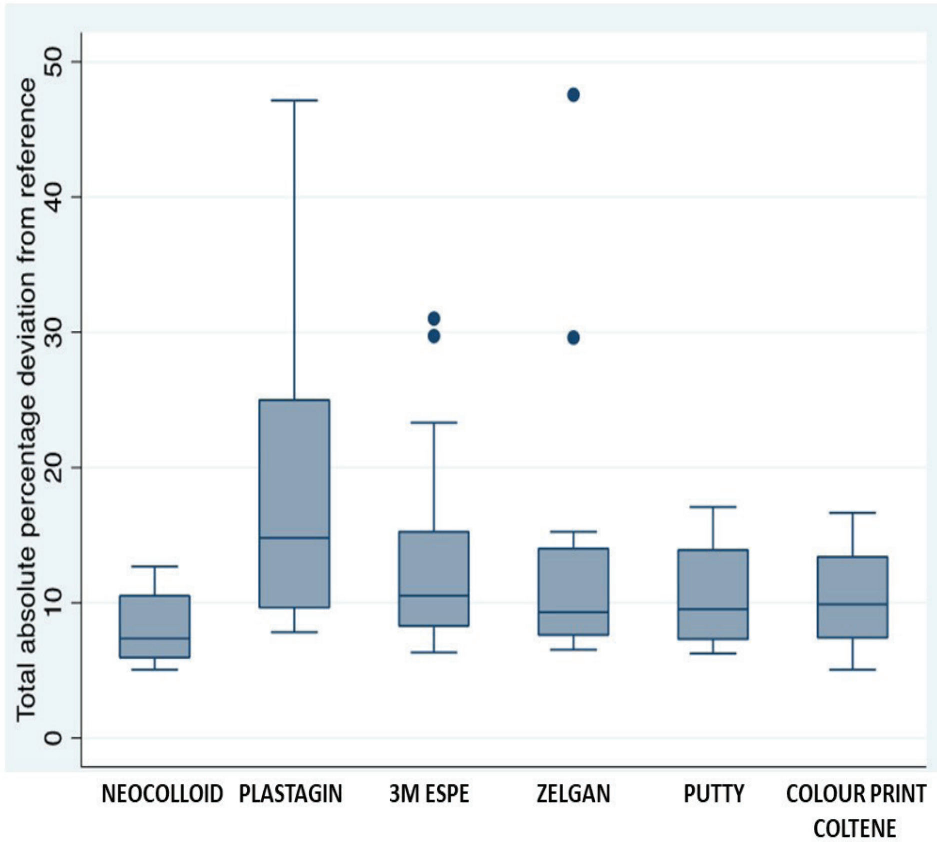


Figure 2: Median total absolute deviation of the stone dies using six impression materials (n=15 for each group)

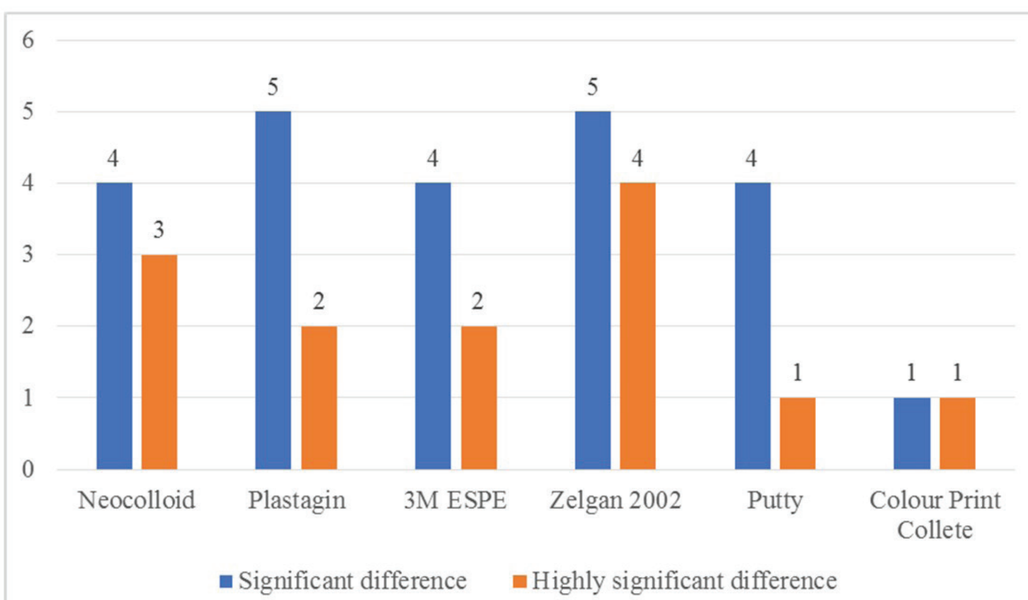


Figure 3: Comparison between the six impression materials in terms of the number of dimensions of the stone dies differing significantly from the stainless steel model (n=15 for each group).

Discussion

The results of the present study support the null hypothesis, as dimensional accuracy of most of newer generation of irreversible hydrocolloid were close to addition silicone (p = .0041). A significant difference among the six impression materials was noted only for dimension m2, m4 and m7, when they were compared with the standard dimensions of master stainless steel model individually (Table-1). This might be due to discrepancies in removals of impression from the master stainless steel model, or polymerization shrinkage of the impression materials. The presence of air bubbles, voids, or tears along the margin of impression, might have led to data related error.[29]

The result showed discrepancies of the stone dies and master stainless model, with positive and negative values, at different abutment dimensions (m1-m9). This would have led to incorrect outcomes, due to positive and negative values annulling each other out. To evade that, the data were transformed to absolute values for comparisons.[15]

In comparison, Neocolloid, Coltoprint, 3M ESPE, and Zelgan resembled closely with Affinis (not being significantly different), with Neocolloid having the minimum median total absolute deviation from the standard reference. However, Plastalgin was having the highest deviation, with a significant difference from Affinis as well as Zelgan and Coltoprint (Table 4). Since the absolute deviations were summed up here, the accuracy of impression materials might not have been significantly different. But as per the rank sum of the deviations from the stainless steel model, it might have seemed that the accuracy of impression materials in decreasing order are Neocolloid >> Affinis >> Coltoprint >> Zelgan >> 3M ESPE >> Plastalgin.

On the contrary, the sequence of dimensional accuracy of impression materials was found to be Coltoprint > Affinis >3M ESPE > Neocolloid > Plastalgin > Zelgan when compared, in terms of the number of dimensions of stone models differing significantly from stainless steel model. Coltoprint and Neocolloid were having a minimum possible deviation from the master model, similar to addition silicone (not being significantly different). Other groups also had a median total absolute deviation similar to addition silicone were 3M ESPE and Zelgan. However, Plastalgin was found to have the highest deviation with a significant difference from addition to silicone (Table 4). Among the irreversible hydrocolloids, Coltoprint was found to be the best material followed by the Neo-colloid.

This outcome was found to agree with the results of some of the previous studies.[30] Peutzfeldt and Asmussen had found the dimensional inaccuracy of the irreversible hydrocolloids to be between 44 and 188 microns. Even dimensional accuracy of one of the irreversible hydrocolloids (Blueprint regular), was comparable with elastomeric impression materials.[30]

Similar results were echoed by Cohen and co-workers. They studied the dimensional stability of conventional brands of irreversible hydrocolloid impression materials under different storage conditions, at different time intervals of 10 min, 30 min, 1 h, and 24 h, before pouring.[31] The most accurate cast was obtained from immediate pouring. In another study, Chen et al had also suggested similar dimensional accuracy of irreversible hydrocolloid to those of elastomeric impression materials, provided it is poured within 24 h.[15] After 24 h, irreversible hydrocolloid impressions are relatively unstable. Faria et al had found the dimensional accuracy of irreversible hydrocolloid to be acceptable, comparable to that of elastomeric impression materials other than polyether, as long as they are poured in time.[11] In contrast, the new generation extended pour irreversible hydrocolloid has been found to maintain dimensional stability up to five days when stored adequately.[16-18] According to Frederic and Caputo, though the precisions of irreversible hydrocolloids are almost those of the elastomeric impression materials, they are inferior, when properties like water loss and the formation of surface roughness are taken into considerations.[25]

There are certain limitations to this study. Being an in vitro study, it does not resemble the oral cavity situation and only provides baseline data. Though the study focuses on the dimensional accuracy, it does not emphasize on the surface detail of the impressions. Moreover, sample sizes taken are small. Further clinical studies with bigger sample studies are required for the successful implementation of the inference of the present study.

Conclusions

Within the limitation of the study, it can be concluded that Neocolloid is the best material with the least possible deviation, with Coltoprint and Affinis closely following it when compared to each other. Plastalgin is the poorest material in terms of accuracy, having a highly significant difference with the best materials. Accuracy is only in terms of diameter and height of abutments and no significant difference between any of these impression materials when inter-abutment distances are concerned. Coltoprint can be regarded as the best material in terms of the least number of dimensions differing from the master stainless steel model.

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