ORIGINAL RESEARCH PAPER

Prosthodontics

COMPARATIVE EVALUATION OF DIMENSIONAL ACCURACY, COMPRESSION RESISTANCE AND SURFACE HARDNESS OF VARIOUS INTEROCCLUSAL RECORDING MATERIALS – AN IN VITRO STUDY

KEY WORDS: Dimensional accuracy, Compressive resistance, Interocclusal recording materials, Surface hardness

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ABSTRACT

For a precise maxillomandibular position, an interocclusal record is needed. The records used for the edentulous and dentulous patients must be reliable with good strength and should able to reproduce the exact maxillomandibular position in an articulator.

AIM AND OBJECTIVES: This study evaluates and compares Dimensional accuracy, Surface hardness and Compression resistance of six different interocclusal recording materials of different manufacturers at three various thicknesses.

MATERIALS AND METHODS: Samples of 2mm, 5mm, and 10mm were fabricated as per the ADA specification no 19 using a stainless steel master die. The materials used were Imprint bite and O- Bite, Coltene speedex and Zetaplus, Aluwax and Maarc wax. Each material was manipulated as per the manufacturer's instructions and placed in the test molds. 360 samples were fabricated with 60 samples in individual group of material comprising subgroups of 20 samples of each thickness. The samples were then subjected to testing procedures for evaluating surface hardness, dimensional accuracy, and compressive resistance.

RESULTS: The testing procedures were performed to analyse dimensional accuracy, surface hardness, and compressive resistance. A significant difference was observed (p-value < 0.01) for the materials when compared with each other.

CONCLUSION: Imprint Bite was found to be having highest surface hardness and dimensional accuracy. O-Bite was having highest compressive strength.

INTRODUCTION:

Replacement of missing teeth can be made by fixed dental prostheses that will improve comfort of the patient, ability of mastication, and maintaining the health and integrity of the maxillary and mandibular arches. In many of the cases, it elevates the patient's self-esteem [1] For proper diagnosis and treatment planning of a particular patient for rehabilitation, the dentist needs to take diagnostic casts and mount them on an articulator. Thus the maxillomandibular relation should be accurately transferred to an articulator. [2]

For a precise maxillomandibular position, an interocclusal record is needed. [3] The records used for the edentulous and dentulous patients must be reliable with good strength and should able to reproduce the exact maxillomandibular position in an articulator. [4,5]

Impression plaster, Impression compound, Zinc oxide-eugenol paste, Acrylic resins, and Waxes are the various materials that have been in usage for recording maxillomandibular relations for many years. [2] The establishment of polyvinylsiloxanes and polyether interocclusal recording media has resulted in making the clinicians think about the decision which material to be used. [6] Furthermore, these interocclusal records must be dimensionally stable for a given time until they are used for the articulation of casts. Accompanying the degree of deformation of the interocclusal record must be nominal or negligible and should not influence the accuracy of mounting the maxillary-mandibular casts in the articulator. [7]

MATERIALS AND METHODOLOGY:

The study consisted of a total of 360 samples, which were divided into 60 samples in each group for each type of material used. The 60 samples were subdivided into 20 samples each for three thicknesses of the test mold.

A master die was prepared as per the Revised American Dental Association (ADA) specification no. 19 for non-aqueous elastic dental impression materials. Using predetermined software, the 3D images and the design of the master die were obtained and were then milled in the CNC milling machine. The master die(stainless steel) has three parts, a ruled cylindrical block AA, an impression material mold or test mold BB, and a riser CC. The ruled block is of 31 mm height and has an inner diameter of 29.97 mm and 38mm outer diameter. This ruled block had three horizontal lines X, Y, Z of different widths.

X line is 50 ± 8 μm, Y line is 20± 4 μm, and the Z line is of 75 ± 8 μm. It also had two vertical lines CD and C´D´. Both the lines were of 75 ± 8 μm width. These vertical lines, CD and C´D´ were separated from each other by 25 mm, approximately 12.5 mm each from the midline. The test mold was a hollow cylinder that was open at both ends. It has an inner diameter of 30 mm and an outer diameter of 38 mm. The test mold was fabricated with three different thicknesses of 2mm, 5mm, and 10mm, to place the manipulated material. The riser was a disk of diameter 29.97 mm and a thickness of 3mm. It was used to remove the set bite registration material from the test molds. (Figure 1A, 1B)

Figure 1A

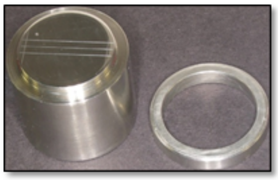


Figure 1B

The materials used for this study were divided into six groups of 60 samples each

GROUP A- MAARC bite registration wax (Aluminium filled wax) **(Figure 2)**

GROUP B- Alu wax (USA) (Bite registration wax) **(Figure 3)**

GROUP C- Zhermack Zeta plus putty (Condensation silicone) **(Figure 4)**

GROUP D- Coltene speedex putty (Condensation silicone) **(Figure 5)**

GROUP E- 3M ESPE Imprint bite (Addition silicone) **(Figure 6)**

GROUP F- DMG O-Bite (Addition silicone) **(Figure 7)**

Figure 2

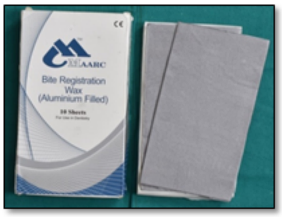


Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

All these study materials were conditioned to ambient room temperature for at least 24 hours before manipulation, and then the bite registration materials were manipulated according to the manufacturer's instructions. After loading into the test molds, a 4× 4 inch glass slab was placed over it, and hand pressure was applied for 5 seconds, followed by the application of a weight of 500 grams on the master die to remove the excess material further.

The whole assembly of the die and the material were then submerged into a water bath of temperature 36 ± 1, which resembles the mouth temperature. After the bite registration material was set, the assembly was removed from the water bath, and the sample was taken out from the molds with the riser. Later the flash (excess material) was trimmed with Bard-Parker blade no. 15. Thus the fabricated samples were measuring 30mm in diameter, 2mm, 5mm, and 10mm in thickness and had the reproduced lines, X, Y, Z, CD, and C´D´ on them. (Figure 8A, 8B) Then the prepared samples were subjected to testing for surface hardness in Shore A hardness tester, Dimensional accuracy in stereomicroscope, and Compressive strength in Universal testing machine.

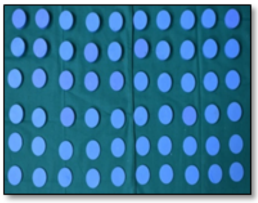


Figure 8A

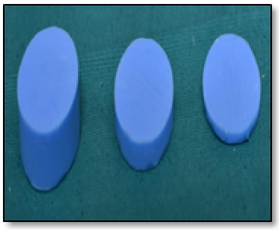


Figure 8B

Testing Procedures:

Dimensional Accuracy:

The distance between both the parallel lines X and Y were determined using Stereo Microscope with a micrometer provision. Before measuring, image analysis software was calibrated to measure two points in microns. Each specimen was then placed on to the platform and magnification of 10X was set, and the field was adjusted the surface between two lines X and Y. The focus was improved, and the image showing the lines was captured. The distance among both parallel reference lines X and Y was measured and noted at two fixed points. The mean average of these two readings was used for calculation of the dimensional change percentage for each sample. The mean measurement of the distance XY in each sample was compared to the corresponding measurement that is present in the standard stainless steel master die that was measured under the same microscope. (Figure 9A, 9B)

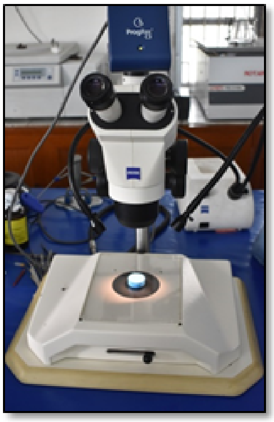


Figure 9A

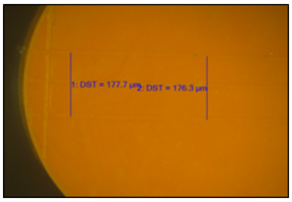


Figure 9B

Surface Hardness:

These samples were again used to evaluate the surface hardness of interocclusal recording materials using Shore A Durometer. For evaluation of these specimens, the depth indicator was initially set to zero, and then a very light force with the index finger was applied to the indenter for 3 seconds, and the unit was lowered on the sample until pressure foot is in full contact. The value was then displayed on the hardness tester. For being accurate, four readings were noted on four different points in the sample, and their mean value was considered for statistical analysis. (Figure 10)

Figure 10

Compressive Resistance:

The samples, at last, were subjected to testing for measuring the compressive resistance in the Universal testing machine (Instron). Two stainless steel bases supported all the test samples and then subjected to a constant compressive load of about 25 Newton with a crosshead speed of 1mm per minute. The distance for which the sample got after 1 minute of load application was compared through appropriate statistical analysis.(Figure 11)

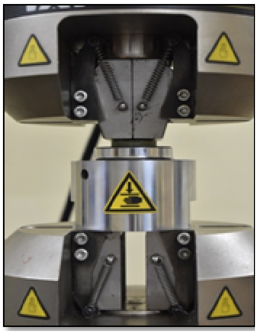


Figure 11

RESULTS:

All the results were subjected to statistical analysis. ANOVA test and independent t-test were performed to measure the significance of the different materials used in the study.

The mean surface hardness of interocclusal record samples of thicknesses 2mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 81.4, 65.73, 68.35, 69.4, 66.7, and 86.93 respectively. The mean surface hardness of interocclusal record samples of thicknesses 5 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 81.73, 65.77, 71.03, 71.83, 68.6, and 86.95 respectively. The mean surface hardness of interocclusal record samples of thicknesses 10 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 83.58, 64.68, 67.58, 71.38, 64.9, and 86.83 respectively.

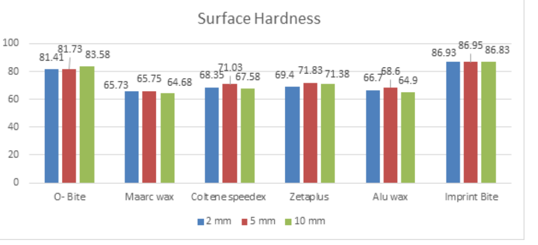
Table 1 shows the comparison of Surface Hardness of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses using ANOVA test. There was statistically significant difference between different materials of 2mm, 5mm and 10 mm. ($p < 0.01$)

Table 1: Comparison Of Surface Hardness Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

Groups	2mm		5mm		10mm		P-value
	Mean	SD	Mean	SD	Mean	SD	
O- Bite	81.41	3.94	81.73	4.34	83.58	3.51	0.89
Maarc wax	65.73	3.91	65.75	3.15	64.68	14.61	0.12
Coltene speedex	68.35	4.25	71.03	3.61	67.58	2.36	<0.01*
Zetaplus	69.4	3.42	71.83	2.2	71.38	2.61	<0.01*
Alu wax	66.7	4.98	68.6	3.02	64.9	13.97	0.19
Imprint Bite	86.93	5.73	86.95	3.34	86.83	5.59	0.35
P-value	<0.01*		<0.01*		<0.01*		

Graph 1 compares the Surface Hardness of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses and it is observed that 5mm sample of imprint bite showed highest hardness while, 10mm sample of Maarc wax showed least hardness.

The mean dimensional accuracy of interocclusal record samples of thicknesses 2mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.00026, 0.00079, 0.00040, 0.00028, 0.00048 and 0.00019 respectively. The mean dimensional accuracy of interocclusal record samples of thicknesses 5 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.00023, 0.00063, 0.00034, 0.00024, 0.00045 and 0.00018 respectively. The mean dimensional accuracy of interocclusal record samples of thicknesses 10 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.00024, 0.0006, 0.00032, 0.00026, 0.00044 and 0.00022 respectively.



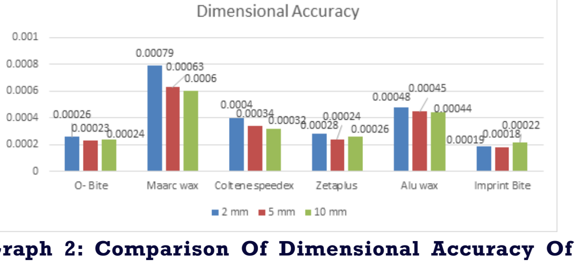
Graph 1: Comparison Of Surface Hardness Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

Table 2 shows the comparison of dimensional accuracy of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses using ANOVA test. There was statistically significant difference between different materials of 2mm, 5mm and 10 mm. ($p < 0.01$)

Table 2: Comparison Of Dimensional Accuracy Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

Groups	2mm		5mm		10mm		P-value
	Mean	SD	Mean	SD	Mean	SD	
O- Bite	0.00026	0.00008	0.00023	0.00006	0.00024	0.00007	0.48
Maarc wax	0.00079	0.0001	0.00063	0.00007	0.0006	0.00007	0.26
Coltene speedex	0.00040	0.00007	0.00034	0.00005	0.00032	0.00006	0.71
Zetaplus	0.00028	0.00005	0.00024	0.00003	0.00026	0.00006	0.56
Alu wax	0.00048	0.00006	0.00045	0.00005	0.00044	0.00007	0.40
Imprint Bite	0.00019	0.00006	0.00018	0.00007	0.00022	0.00007	0.49
P-value	<0.01*		<0.01*		<0.01*		

Graph 2 compares the dimensional accuracy of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses and it is observed that 5mm sample of imprint bite showed highest dimensional accuracy while, 2mm sample of Maarc wax showed least dimensional accuracy.



Graph 2: Comparison Of Dimensional Accuracy Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

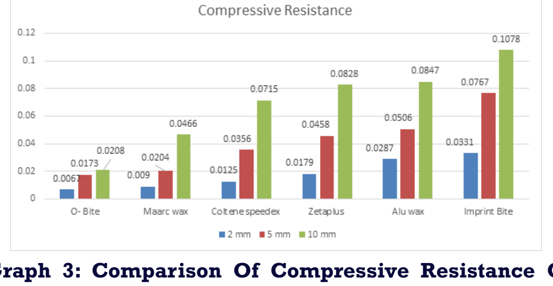
The mean compressive resistance of interocclusal record samples of thicknesses 2mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.0067, 0.009, 0.0125, 0.0179, 0.0287 and 0.0331 respectively. The mean compressive resistance of interocclusal record samples of thicknesses 5 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.0173, 0.0204, 0.0356, 0.0458, 0.0506 and 0.0767 respectively.

The mean compressive resistance of interocclusal record samples of thicknesses 10 mm of O-Bite, Maarc wax, Coltene speedex, Zetaplus, Aluwax and Imprint bite was obtained as 0.0208, 0.0466, 0.0715, 0.0828, 0.0847 and 0.1078 respectively. Table 3 shows the comparison of compressive resistance of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses using ANOVA test. There was statistically significant difference between different materials of 2mm and 5mm. ($p < 0.05$)

Table 3: Comparison Of Compressive Resistance Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

Groups	2mm		5mm		10mm		P-value
	Mean	SD	Mean	SD	Mean	SD	
0- Bite	0.0067	0.0092	0.0173	0.0195	0.0208	0.0501	<0.01*
Maarc wax	0.009	0.0074	0.0204	0.0122	0.0466	0.0428	<0.01*
Coltene speedex	0.0125	0.0288	0.0356	0.0652	0.0715	0.1025	<0.01*
Zetaplus	0.0179	0.019	0.0458	0.0645	0.0828	0.086	<0.01*
Alu wax	0.0287	0.0442	0.0506	0.0862	0.0847	0.0737	<0.01*
Imprint Bite	0.0331	0.0479	0.0767	0.0578	0.1078	0.1737	<0.01*
P-value	0.03*		<0.01*		0.0900		

Graph 3 compares the compressive resistance of different interocclusal record materials at 2mm, 5mm, and 10mm thicknesses and it is observed that 2mm sample of O-bite showed highest compressive resistance while, 10mm sample of Imprint bite showed least compressive resistance.



Graph 3: Comparison Of Compressive Resistance Of Different Interocclusal Record Materials At 2mm, 5mm, And 10mm Thicknesses.

DISCUSSION:

Indirectly made prostheses such as fixed dental prostheses and single crowns should be cemented in the oral cavity with least or no occlusal adjustments. So, to fulfill this need, an accurate and precise bite registration material is required. An ideal interocclusal record allows the intraoral placement of restorations without considerable changes.[8,9]

Deformations in the records vary with the thickness of the material used, type, and manufacturer as well. Waxes are selected as they are the commonly used bite registration materials in the clinics. They are readily available and also cost-effective. Condensation and addition silicones were selected as they are newly developed materials. The different thicknesses of the interocclusal recording materials were taken to simulate the clinical situations. The thinner samples would match the limited space between the prepared teeth on one arch opposing unprepared teeth compared with the medium thickness samples used between two opposing maxillary and mandibular arches in full mouth rehabilitation cases and the larger thickness for partially edentulous conditions.[10,11] The hardness of the bite registration material is essential, as it can ensure distortion-free interocclusal records. Solid highly filled materials were found to exhibit the least vertical discrepancies because of reduced polymerization shrinkage and also the ability to withstand deformation ensuring more precise fit on dental stone casts. [12]From the results, it was observed that hardness values were highest at 5mm thickness for all the groups except for O- Bite samples. G. Anup et al., in an original study, evaluated the surface hardness of various interocclusal recording materials and disclosed that hardness was more for polyvinyl siloxane and then followed by Zinc oxide eugenol and Aluwax. [8] Arjun N. Mithra et al. found that the significant increase in the surface hardness was noticed in imprint bite, Futar D, and polyether, up to the first 48 hours later, no significant change in the hardness was seen. [12]

From the results, it was found that dimensional accuracy of samples does not vary with the change in their thickness which was in accordance with the study conducted by Shikha Gupta which showed that there is no significant significance in linear dimensional change among different thicknesses of different materials and dimensional stability is independent of thickness of the material. [13]

Waxes presented the most significant dimensional changes among all the materials tested above. This was explained by both the high coefficient of thermal expansion of wax and the release of internal stresses that could lead to wax distortion. [14] Studies also showed that waxes contain aluminum or copper particles with a flow rate of 2.5- 22% at 37.5 degrees, so they are susceptible to distortion upon removal from the mouth. [8] The loss of accuracy of condensation silicones may be due to the formation of voids or air bubbles on the surface, which may be due to the hydrophobic nature of this material. It may also be due to the more extended polymerization period resulting in sustained contraction period and shrinkage period. [15] Addition silicones are more dimensionally stable than condensation silicones and waxes.

Generally, rubber bands can be used to sustain the contact of opposing casts of both the jaws during articulation. The maximal force exerted by the use of one office standard rubber band (number 19) to position a maxillary cast to an opposing mandibular cast mounted on an articulator was approximately 25 N, so this value was selected as a load to be applied in this investigation. [10,11,16]

From the results, it was found that for all the groups of samples as the thickness was increased the resistance to closure that is the compressive strength was decreased which was correlated with the research studies of Maj P Dua, Breeding LC, Rahul Nagrath and Dixon who showed that thicker elastomeric interocclusal registration media are generally more compressible. [7, 11, 16] The reason for higher compression strength of addition silicones may be due to its low dimensional change compared to condensation silicones and waxes. [17] Konstantinos X. Michalakis et al. investigated the strength to compression after setting of various materials. They found that polyvinyl siloxane exhibited the highest resistance to closure when correlated to zinc oxide- eugenol paste and wax. [18]

Limitations Of The Study:

1. Dimensional errors are three dimensional, and this study measures only the linear dimensional change as a parameter for determining dimensional accuracy similar to routine clinical situations. Dimensional variations may occur in the anteroposterior, vertical, and even in mediolateral position.

2. As this is an in-vitro study, the samples tested were not able to simulate the oral environment as it might slightly alter the results.

CONCLUSION:

Within the confined limitations of this study, it was concluded that:
1. Dimensional stability is independent of thickness and showed no statistical significance among different

thicknesses in all the materials. There was a statistical significance in 2mm, 5mm, and 10mm thicknesses.

Imprint bite > O- bite> Zeta plus putty> Coltene speedex putty> Alu wax> Maarc wax.

2. 5mm thick samples showed the highest hardness in all materials except in O- Bite. There was no statistical significance among different thicknesses in all the materials individually except in Coltene speedex and Zeta plus putty. There was a statistical significance in 2mm, 5mm, and 10mm thicknesses.

Imprint bite > O- bite> Zeta plus putty> Coltene speedex putty> Alu wax> Maarc wax.

3. The compressive strength of the material decreased as the thickness of the sample increased, and there was a statistical significance among various thicknesses. There was a statistical significance in 2mm, 5mm, except in 10mm thickness.

O- Bite > Imprint bite> Zeta plus putty> Coltene speedex putty> Maarc wax> Aluwax.

Therefore it was recommended that clinicians should consider addition silicones as they showed better properties than condensation silicones and waxes, and among the various thicknesses tested, 2mm thick samples showed the highest compressive strength than 5mm and 10mm. 5mm thick samples showed the highest hardness when compared to 2mm and 10mm, and dimensional accuracy was independent of the thickness of the sample.

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