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Comparison of the accuracy and dimensional stability of interocclusal recording materials - An in- vitro study.

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Abstract- Purpose: The purpose of this in vitro study was to compare and correlate the accuracy and dimensional stability of commonly used interocclusal recording materials.

Materials and methods: A stainless steel die, made according to modified ADA specification no. 19, was loaded with different interocclusal recording materials. These materials were separated from die 3 min after their respective setting time, which resulted in disks of standard diameter with two parallel lines and three perpendicular lines (thin, medium and thick) on the surface.
These lines were observed under Nikon profile projector V-12 and graded for line and shape criteria to find out the accuracy of the material. The distance between two parallel lines was measured at different time intervals to find out the dimensional stability of the material.

Statistical analysis used: ANOVA followed by Mann-Whitney test for pair wise comparison

Results: There was significant difference found between accuracies of different interocclusal recording materials. Zinc oxide eugenol and polyether were more accurate than silicon and Aluwax. The comparison of dimensional stability showed that zinc oxide eugenol and polyether were more dimensionally stable followed by silicon. Aluwax was least dimensionally stable of all.

Conclusions: The zinc oxide eugenol is more accurate interocclusal recording material and which is followed by polyether, silicon and Aluwax respectively. Poly ether, zinc oxide eugenol and silicone possess good dimensional stability. No correlation exists between accuracy and dimensional stability of interocclusal recording materials.

Key-words: Interocclusal recording material; Bite registration material; Accuracy; Dimensional stability

INTRODUCTION:

Diagnosis and treatment of a patient for prosthetic rehabilitation requires the clinicians to fabricate diagnostic cast, as well as master cast and articulate. In some cases, the casts can be easily mounted in maximum intercuspation by stabilizing them with cast cement after hand articulation. While in others, it is necessary to record maxillomandibular relationship and accurately transfer it to the articulator by using appropriate interocclusal recording medium (1). The use of ideal material and proper technique allows the placement of indirectly fabricated prosthesis in the patient's mouth with minimal occlusal adjustment.

Phillip Pfaff made the first interocclusal registration in 1756, since then many materials and techniques have been used for maxillomandibular relationship record. These materials are basically impression materials but that have been modified to give better handling characteristics(2). These include impression plaster, waxes, zinc oxide eugenol, acrylic resin, hydrocolloids, and newer ones include polyether and vinyl polysiloxane. Both waxes and zinc oxide eugenol are most commonly used interocclusal recording materials because of their ease of manipulation, economy, less time consuming and less skill dependent. These materials serve as base line for newer developments in the interocclusal recording materials.

Requirements for ideal interocclusal registration material include; a) It should have limited resistance before setting to avoid displacement of teeth or mandible during closure. b) It should become rigid and exhibit minimal dimensional change after setting. c) It should produce accurate record of the incisal and occlusal surface of the teeth d) It should be easy to manipulate. e) It should not produce adverse effects on the tissues involved in procedure and it should allow easy verification (1).

But no material has all the properties of the "ideal" interocclusal registration material. The inaccuracies attributed to the interocclusal records can be divided into three categories: the biologic characteristics of stomatognathic system, manipulation of the material, and the properties of the interocclusal recording materials (3).

Many studies have been conducted to find the accuracy and dimensional stability of several bite registration materials (2-10). In an experimental study on physical properties of interocclusal recording materials, the Polyether interocclusal recording material exhibited lesser linear change than Silicon and Zinc oxide eugenol, which was not associated with their respective weight loss (2).

In another study on differential accuracy of Silicon interocclusal recording materials, the authors found that a direct relationship exists between dimensional stability and percentage of weight loss (8), but no study has been done to correlate the accuracy and dimensional stability.

Hence, this study was planned to compare and correlate the accuracy and dimensional stability of four commonly used inter-occlusal recording materials.

MATERIALS AND METHODS:
Four commercially available interocclusal materials were evaluated.

1) Bite registration wax (Aluwax, Aluwax Dental Product Co., Michigan USA).

2) Polyether bite registration paste (Ramitec, 3M ESPE, AG Dental Products, Germany Lot 268467).

3) Vinylpolysiloxane bite registration cream (Exabite II NDS, GC America Inc, ALSIP, IL, Lot 0602061).

4) Zinc–oxide eugenol bite registration paste (Superbite, Bosworth Company, Skokie, IL lot 0608-395).

Materials and method followed in this study has been discussed under the following headings.

1) Preparation of mold.
2) Selection and manipulation of materials.
3) Preparation of samples.
4) Observation made for scoring the samples for accuracy.
   i) Observation of continuity of lines.
   ii)Observation of shape of the thick line.
5) Measurement of the distance between lines for determining dimensional stability.

1) **<u>Preparation of mold: -</u>**

A mold was prepared according to revised American Dental Association specification no. 19 for non-aqueous elastic dental impression materials (11).

It was consist of a ruled block AA, test material mold BB and a riser CC. All parts were made up of stainless steel except raiser, which was made up of brass.

The ruled block was having three horizontal lines of different widths; small Y -line (width-24mm), medium X-line (width-57 mm) and a thick Z line (width –83mm). And two vertical lines CD and C'D' of 82mm each. The lines CD and C'D' were separated from each other by 25mm approx. (24.740mm) (fig.1&2).

The test material mold was a cylinder of inner diameter 30mm and depth of 6mm.

The riser was a brass disc of diameter 29.9mm and thickness of 3mm.

2) **<u>Selection and Manipulation of materials:-</u>**

Four commonly used interocclusal recording materials were selected for the purpose of this study. All the materials were purchased from local market through regular commercial channels.

The materials used for the study were divided into four groups of 10 samples each.

Group 1: - Bite registration wax (Aluwax)

Group2: - Polyether registration paste (Ramitec)

Group 3: - Polyvinyl siloxane bite registration cream (Exabite II NDS)

Group 4: - Zinc oxide eugenol bite registration paste (Superbite)

Altogether, a total of forty samples were prepared. All the study materials were conditioned to ambient room temperature for at least 24 hrs before manipulation and the individual materials were manipulated following the manufacturers' instructions.

3) **<u>Preparation of samples:-</u>**

Each material was manipulated as mentioned above and the total force of 5.56 N (weight of glass plate 67g + external weight 500g = 567g) was applied. This is the average pressure required to compensate initial resistance of interocclusal material which may vary between 0.5 N to 13.8 N (12).

The whole assembly was then submerged in water bath of temperature 32 ± 1^0C resembling mouth temperature. Each assembly remained in the bath for the setting time suggested by manufacturer plus 3 min to ensure polymerization in case of elastomeric materials.

After removal from the water bath, the material was separated from the die by using the brass disk (riser). The excess flash was trimmed using a Bard Parker knife. Thus prepared specimens were measuring 30 mm in diameter, 3mm in thickness and had the lines X, Y, Z, CD and C^I D^I lines on it. Similarly, all the 40 bite registration record samples were obtained. (fig. 3)

In between days of observation, the samples were stored in a moisture free polyethylene bags at room temperature of 28 ± 2^0C. Dimensional changes of elastomers can be reduced by storage in a sealed dry container (12, 13) and at room temperature air (12).

4) **<u>Observation made for scoring the samples for accuracy:</u>**

- Accuracy of different interocclusal recording materials was determined by observing each sample under Nikon Profile Projector V-12 (Nikon inc., Japan) with the accuracy of 0.001mm. (fig 4) Observations for accuracy were made immediately after obtaining the samples only on the day 1.
- Each sample was graded group wise according to line criteria and shape criteria.

Following criteria were used for grading the samples.

(i) Observation for continuity of lines reproduced (line criteria):

Thinnest continuous line produced by each material was observed by using Nikon Profile Projector V-12 with 50 X magnification and the scores were noted.

Score	Observation
0	No continuous line
1	Continuous thick line (Z-line)
2	Continuous medium line (X-line)
3	Continuous thin line (Y- line)

(ii) Observation for the shape of the line reproduced (shape criteria):

The shape of 'Z' line reproduced on the surface of the sample was observed by using Nikon profile Projector V-12 with 50 X magnification, compared with V-shaped line on the master die and scores were noted to check the accuracy.

Score	Observation.
1	Rounded
2	Combination of rounded and V- shaped.
3	V-shaped.

The scores obtained for both continuity of lines (line criteria) and shape of the line reproduced (shape criteria) were subjected to statistical analysis for comparing the accuracy of four interocclusal recording materials.

1) OBSERVATION OF SAMPLES FOR DIMENSIONAL STABILITY :

The distance between the lines, CD and $C^I D^I$, reproduced on the samples, was measured at three different points PP^I, QQ^I and RR^I (i.e. at the intersections of these lines with the lines XYZ) (see fig 2) by using Nikon Profile projector V-12 with 10 X magnification. Three readings were obtained for each sample and the averages of these three values were noted. Likewise readings were made at different time intervals i.e.; immediately after removal of the material from the die, on second day, on eighth day and on fifteenth day respectively for each of the samples. All the readings thus obtained were tabulated and subjected to statistical analysis for the comparison and correlation of accuracy and dimensional stability of four interocclusal recording materials.

STATISTICAL ANALYSIS:

Results are expressed in mean ± SD, median , mode and sum of scores. One way ANOVA was used for inter group comparison and Mann- Whitney test for pair wise comparison of accuracy and dimensional stability of four interocclusal recording materials. A p- value of 0.05 or less was considered for statistical significance.

RESULTS:

Comparison of the accuracy of four interocclusal recording materials by line criteria and shape criteria was done. In the line criteria, the sum of the scores and mode of scores that Zinc oxide eugenol was more accurate followed by Polyether and Silicon, while Aluwax was the least accurate. The analysis of variance was significant in line criteria ($F=10.30$, $p<0.05$). (Table -1)

The pair wise comparison between the materials using Mann-Whitney test showed significant difference between accuracy of Aluwax & Polyether, Aluwax & Silicon bite registration paste, Silicon & Zinc oxide eugenol and between Aluwax & Zinc oxide eugenol bite registration pastes ($p<0.05$). The accuracy of Polyether & Silicon, Polyether & Zinc oxide eugenol did not differ significantly ($p>0.05$).

As per the shape criteria also the Aluwax was the least accurate material in reproducing the shape of lines. The analysis of variance was significant in shape criteria ($F=10.83$, $p<0.05$).(Table-1)

The pair wise comparison showed that there were significant differences seen between the accuracy of Aluwax & Polyether, Aluwax & Silicon and Aluwax & Zinc oxide eugenol ($p<0.05$). No significant changes were seen between Polyether & Silicon, Polyether & Zinc oxide eugenol bite registration pastes and Silicon & Zinc oxide bite registration pastes ($p>0.05$).

Together line and shape criteria suggest that Zinc oxide eugenol and Polyether interocclusal recording materials are equally accurate followed by Silicon and Aluwax respectively.

The comparison of distance between lines (dimensional stability) at different time interval for four interocclusal recording materials was done by using ANOVA. The analysis of variance showed no significant difference between all the materials on day1 ($F=0.93$, $p>0.05$). But, there was significant difference seen between these materials on 2nd day ($F=3.42$, $p<0.05$), 8th day ($F=6.35$, $p<0.05$) and 15th day ($F=6.36$, $p<0.05$). The pair wise comparison of dimensional stability of four interocclusal recording materials on different days by using Mann Whitney test showed no significant difference between all materials on day 1 ($p>0.05$ for all). On day 2, significant difference was seen between Zinc oxide eugenol and Aluwax ($p<0.05$) and it was highly significant between Silicon and Aluwax ($p<0.001$). On the day 8, significant difference was seen between Polyether and Aluwax and highly significant between Silicon and Aluwax ($p<0.001$). On the 15th day, Aluwax showed significant difference from all other materials. On all these days, there was no significant difference found between dimensional stability of Zinc oxide eugenol & Polyether, Zinc oxide eugenol & Silicon and Silicon & Polyether bite registration materials ($p>0.05$). (Table 2).

From the statistical analysis of data, following results were obtained-

1. Among the four interocclusal recording materials tested for their accuracy the Zinc oxide eugenol bite registration paste was found to be more accurate which was followed by Polyether, Silicon and Aluwax respectively.

2. Within first 24 hrs, all the interocclusal materials were dimensionally stable.

3. Polyether, Silicon and Zinc oxide eugenol are equally dimensionally stable over the period of 15 days.

4. Further, the statistical analysis did not reveal any correlation between accuracy and dimensional stability of the four interocclusal recording materials (i.e. Zinc oxide eugenol, Polyether, Silicon and Aluwax). But from the present study, ZnOE was most accurate and dimensional stable material. While Polyether and Silicon did not reveal any significant changes and almost exhibited equal amount of accuracy and dimensional stability.

Discussion:

During restorative phase of any dental treatment, the precise articulation of patient's diagnostic or working casts is a prerequisite for fabrication of clinically acceptable prosthesis. Apart from the operator's clinical ability and the technique followed, the chosen material can affect the accuracy of the interocclusal registration and thereby final outcome of the restoration.
Interocclusal recording materials like wax and Zinc oxide eugenol are used for recording maxillomandibular relationship. The introduction of Polyether and Polyvinyl siloxane interocclusal recording materials has made clinicians unsure of which material they should use. These elastomeric materials are chemically similar to the impression materials that have been used for many years (14). Modifications have been made by adding plasticizers and catalyst to provide different handling characteristics (2) ; however, it remains unknown whether these modifications in the parent impression materials have altered their properties like accuracy and dimensional stability. Hence, present in-vitro study was planned to compare the accuracy and dimensional stability of four commonly used interocclusal recording materials and to find out any relation if it exists between them.

Since half of the samples made for the study were of elastomeric interocclusal recording material, the method chosen to compare the accuracy and dimensional stability was as per the testing methodology of ADA specification no.19 – for elastomeric impression materials (11) .

However dimensional stability can also be studied in all the three planes by using equipments like condymeter (3), computer axiotran (15) , Buhnergraph(5) and hydro-optic test & measurement system (7, 8) .

The time intervals used in the study were selected considering the time taken to carry interocclusal recording materials to distant laboratories or delay in articulation or remounting of the casts if required, simulating the clinical situation as mentioned in previous study (10).

Waxes are most commonly used interocclusal recording materials, because of their ease of manipulation and cost effectiveness. Considerable controversy exists regarding the accuracy, usefulness and manipulative skills required in obtaining accurate interocclusal records. The accuracy of an interocclusal recording wax must be considered in terms of the many variables responsible for dimensional changes. Even under the highly controlled conditions, the exact reproduction of the original wax recording was never achieved (6).

In this study, Aluwax was used. Aluwax is consisting of low viscosity wax with impregnated aluminum particles to evenly disperse the heat and to avoid excessive cooling contraction. Waxes were repeatedly shown to be most inaccurate interocclusal recording materials (3,12,16,17) . In this study also Aluwax was found to be least accurate to reproduce the surface details.

Waxes were found to be dimensionally unstable; this is because of their greater coefficient of thermal expansion. Also, they show distortion while removal (2) from mouth and considerable contraction on cooling.(12) This study, Aluwax was found to be least dimensionally stable. However the Aluwax exhibits good dimensional stability on 1st day, so can be used if the mounting procedures to be carried out immediately.

Zinc oxide eugenol is another commonly used interocclusal recording material. It is generally used to correct the interocclusal record made by wax. It is shown to reproduce accurate surface details mainly because of its low initial viscosity coupled with its pseudo elastic nature, which allows fine detail reproduction (18). It also exhibits greatest flow characteristics when compared with the polyether , polyvinyl siloxane and wax. More over, Zinc oxide eugenol offers no resistance to closure of mandible thus allowing a more accurate interocclusal relationship record to be formed.

In the present study, Zinc oxide eugenol was found to be more accurate material in terms of detail reproduction. This is because the surface detail reproduction depends mainly upon the flow characteristics of the materials. Zinc oxide eugenol was found to be dimensionally stable. It showed contraction over the period of 15 days but was not statistically significant.

Polyether bite registration paste is getting popularity because of its ease of manipulation and accuracy. Polyether exhibited greater flow characteristics than Addition Silicon and Waxes. Polyether is most accurate amongst the materials used. Polyether sets by polymerization reaction so there will be volumetric shrinkage of the material during the reaction. Polymerization shrinkage was seen to be more in first 24-hrs i.e. on 2nd day. But afterwards, no significant shrinkage was noted. During the test period Polyether didn't show any significant change in dimensions ($p>0.05$).

Silicon has less flow due to high viscosity, very fast construction of polymer chains and fast transition from the plastic to the elastic phase. The flow Silicon bite registration paste was found to be lower than Polyether and Zinc oxide eugenol (1).

In the present study, polyvinylsiloxane (Silicon) was found to be inferior in accuracy when compared to Zinc oxide eugenol and Polyether. But there was no significant difference found between Polyether and Polyvinyl siloxane. It was significantly good in accuracy when compared with Aluwax. The loss of accuracy was mainly due to formation of air bubbles on the surface which might be because of hydrophobic nature of the material.

Polyvinyl siloxane displayed linear dimensional change and weight loss due release of hydrogen gas. Most manufacturers add platinum or palladium as scavenger in Polyvinyl siloxane impression paste. To date however, there is no published paper to support that there is also a scavenger in interocclusal registration material since there is no need for these materials to be poured with stone (2) .

Silicon has shown significant change in dimensional stability after 8 days ($p< 0.05$). The reason might be that Silicon has longer polymerization period than Polyether resulting in sustained contraction period with shrinkage period of over two weeks. This result confirms earlier experimental results, Silicon bite registration paste undergoes sustained contraction even after 168 hrs (10).

Statistical analysis of results does not reveal any correlation between accuracy and dimensional stability. Hence, it can be said that both of these properties should be considered differently while selecting material for making interocclusal records.

The limitation of this in-vitro study was that it considered only the linear measurement as a parameter for determining dimensional stability, but in routine clinical practice, dimensional errors in interocclusal registrations occurs in all three dimensions.

CONCLUSION

Within the limitations of this study, it was concluded that, among the four interocclusal recording materials tested for their accuracy the Zinc oxide eugenol bite registration paste was found to be more accurate interocclusal recording material and which was followed by Polyether, Silicon and Aluwax respectively. Polyether, Silicon and Zinc oxide eugenol were found to be the more dimensionally stable than Aluwax. No correlation exists between the accuracy and dimensional stability of the four tested interocclusal recording materials.

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Conflict of Interest: 'The authors declare no conflict of interests'.

Author contribution : I/we certify that I/we have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript, to take public responsibility for it and have agreed to have my/our name

listed as a contributor. I/we believe the manuscript represents valid work.

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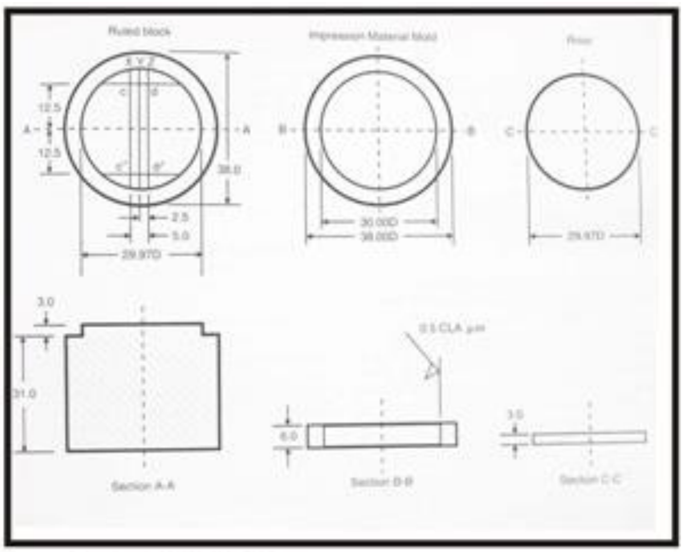

Section A-A: Ruled block
Section B-B: Impression material mold
Section C-C: Riser
(* all measurements in mm)

Fig. 1. Schematic diagram showing ADA specifications no 19 detail reproduction block

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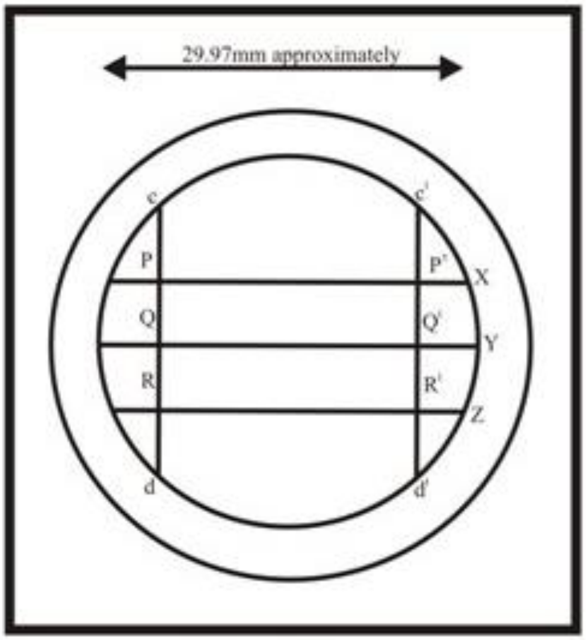

Line width

Line X: 50 +/- 8µm
Line Y: 20 +/- 4µm
Line Z: 75 +/- 8µm
Line CD: 75 +/- 8µm
Line C'D': 75 +/- 8µm
Distance between lines CD and C'D' = 25mm (approx.)

Fig. 2. Schematic diagram showing ruled surface of reproduction block

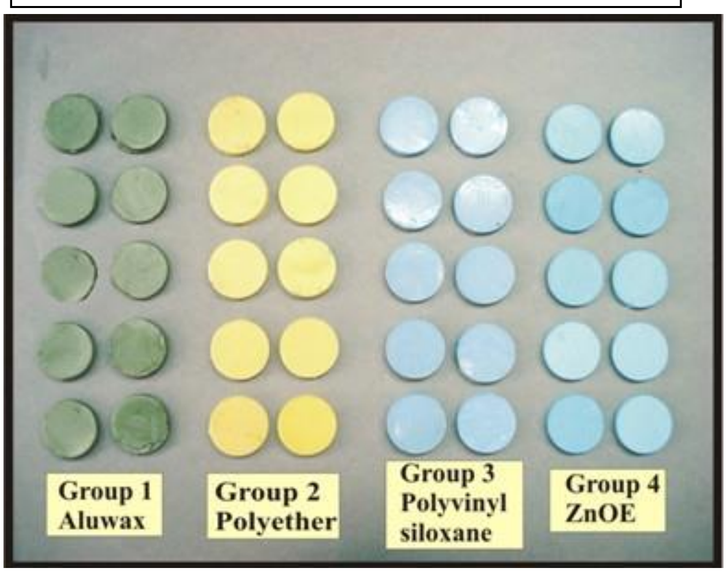

Fig 3: Samples produced from the die

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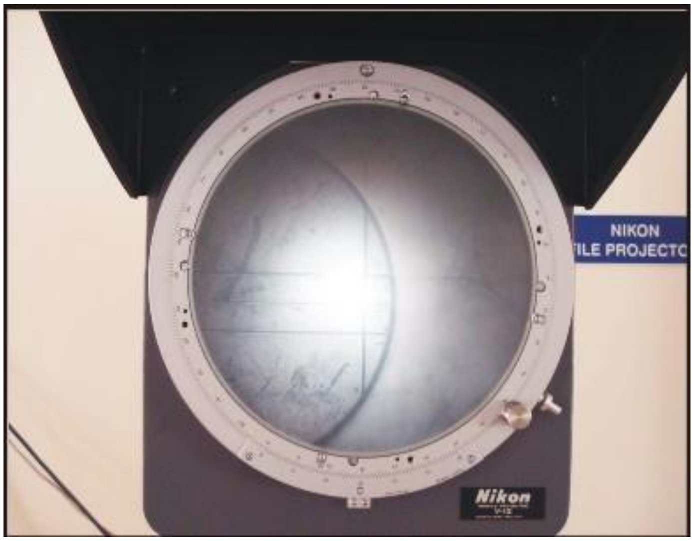
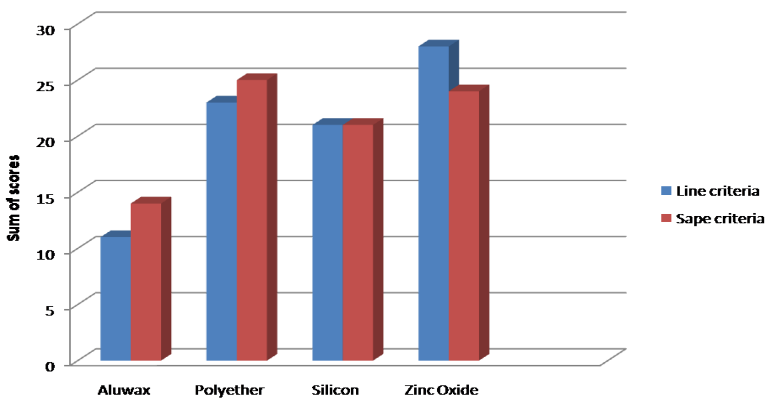
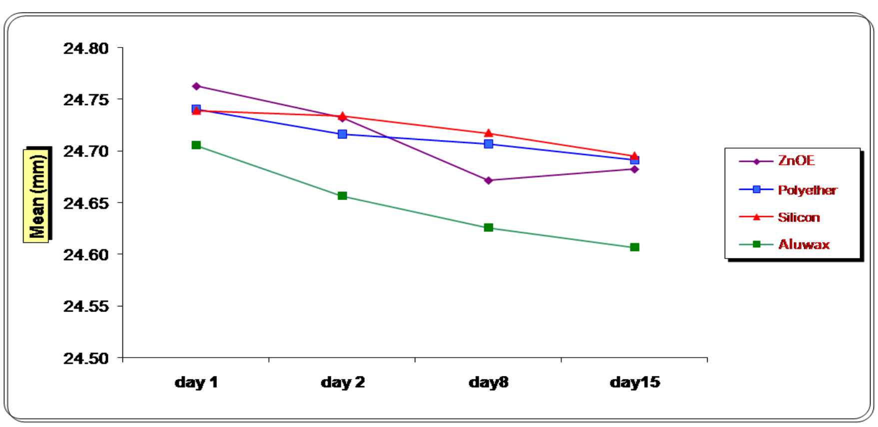


Fig 4: Nikon Profile Projector V-12 (Nikon inc., Japan) with the accuracy of 0.001mm.



Graph 1: Showing comparison of accuracy of four interocclusal recording materials



Graph 2: Showing dimensional stability of four interocclusal recording materials

Table 1: Showing the comparison of accuracy of four interocclusal recording materials (ANOVA).

Materials	Line Criteria								Shape criteria						
	Scores				**Mean ± SD**	Median	Mode	Sum	Scores			**Mean ± SD**	Median	mode	sum
	0	1	2	3					1	2	3				
Aluwax	2	5	3	-	1.1±0.7	1	1	11	6	4	-	1.4±0.5	1	1	14
Poly ether	-	2	3	5	2.3±0.7	2.5	3	23	-	5	5	2.5±0.5	2.5	3	25
Silicon	-	2	5	3	2.1±0.7	2	2	21	-	9	1	2.1±0.3	2	2	21
ZnOE	-	-	2	8	2.8±0.4	3	3	28	-	6	4	2.4±0.5	2	2	24
ANOVA	F = 10.30, p< 0.05, Significant								F = 10.83, p < 0.05, Significant						

Table 2: Showing comparison of dimensional stability of four interocclusal recording materials

Days Materials	Day1	Day2	Day8	Day15
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Aluwax	24.705 ± 0.020	24.656 ± 0.010	24.626 ±0.024	24.607 ± 0.017
Polyether	24.740 ± 0.068	24.716 ± 0.082	24.707 ± 0.056	24.691 ± 0.065
Silicone	24.739 ± 0.015	24.734 ± 0.014	24.717 ± 0.017	24.695 ± 0.017
ZnOE	24.763 ± 0.137	24.731 ± 0.092	24.671 ± 0.082	24.682 ± 0.078
ANOVA	F = 0.93 p = 0.44, NS	F = 3.42 p < 0.05, S	F = 6.35 p < 0.05, S	F = 6.36 p < 0.05, S