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Evaluation of the tear strength, compressive resistance, and surface hardness of three commercially available bite registration materials: an *in vitro* study

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INFORMATION

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ABSTRACT

Background: For making a successful prosthesis, it is essential to achieve harmony between the maxillomandibular relationship. The precision and occlusal quality of the prosthesis partly depends on interocclusal bite registration material. Interocclusal bite registration material plays an important role in recording and transferring of existing patient's occlusal records. The procedure used to record and transfer interocclusal relation should be performed with the utmost care and understanding to prevent clinical error.

Aim: This study aimed to evaluate the tear strength, compressive resistance and surface hardness of three commercially available bite registration materials .

Materials and methods: Three types of commercially available bite registration materials, Bis-acrylate (BA), Polyvinylsiloxane (PVS), and Polyether (PE), were made in Dumbbell and cylindrical shaped samples to evaluate the tear strength and compressive resistance, respectively and were analysed using the universal testing machine. The surface hardness was assessed using a microhardness tester. The obtained data were subjected to statistical analysis using SPSS 16.0 version (Chicago, Inc., USA). ANOVA/Kruskal-Wallis test was used to compare study parameters among the groups. Tukey's post-hoc test was used for inter-group comparisons.

Results: Bis-Acrylate exhibited the greatest tear strength, followed by Poly vinylsiloxane and Polyether showed the least tear strength. More compressive resistance was observed in Polyether followed by Bis-Acrylate and lowest in Polyvinylsiloxane. A similar pattern was seen in the surface hardness among the three materials.

Conclusion: Bis-acrylate showed greater tear strength and surface hardness, and it can be considered a better bite registration material.

1. Introduction

Interocclusal bite registration materials are partly responsible for accurate precision and occlusal quality of final prosthetic restorations used for mounting casts on the articulators. Accurate mountings can lead to restorations that require minimal occlusal modifications intraorally, thus reducing the chairside time [1]. Diagnosis and treatment planning procedures may be inadequate if casts are fixed in an inaccurate position. The procedure used to record and transfer interocclusal relations should be performed with the utmost care and understanding [1].

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Historically, various materials used for inter-occlusal registration are thermoplastic materials like waxes or chemically set materials such as dental plaster, Zinc Oxide Eugenol (ZOE) paste and recently developed elastomeric impression materials [3,4]. The first material used was impression plaster with some filler materials. However, dental plaster is difficult to manipulate, making space for dental waxes [4]. Waxes are used alone or in combination with other materials. However, waxes tend to undergo distortion if not appropriately handled. ZOE paste was considered as one of the best interocclusal recording material. However, this paste has few shortcomings like longer setting time, sticky to the teeth and brittleness. Vital portions of the record are lost through breakage on removal from the mouth. Hence, ZOE records are rarely used.

Some clinicians also tried acrylic resin, and it is most frequently used in the fabrication of single stop centric occlusion records. Acrylic resin is accurate and rigid after setting with few demerits like dimensional instability and rigidity [5]. A modelling compound was used to fabricate segmental interocclusal records. Errors observed were the flow of the material over axial surfaces of teeth and soft tissues, which invites errors in re-positioning working casts within the bite registration and abrasion of the working cast during mounting [5].

Recently, addition silicones and polyether impression materials have been modified by adding plasticisers and catalysts in order to be used as interocclusal records. They are popular because of their resistance to compression, surface hardness, high tear strength, dimensional accuracy and stability [6]. A compressive force is commonly exerted on the interocclusal recording material during the articulation procedure, which may cause inaccuracy during mounting of cast and distortion during fabrication of the restoration. The ability of an interocclusal recording material to resist compressive force is critical because of the potential for inaccuracies. The deformation may vary with the thickness and the properties of the recording materials used[1]. Similarly, the hardness of the material can reduce shrinkage and resist deformation [7]. Tear strength can likewise record the bite with precision and accuracy [8]. The present study was undertaken to evaluate and compare the tear strength (TS), compressive resistance (CR) and surface hardness (SH) of three commercially available bite registration materials to determine the one with the least inaccuracies.

2. Materials and methods

Three commercially available bite registration materials used in the study were PVS bite registration material (3M™ Imprint™ 4 VPS Impression Material) (Figure 1), PE bite registration material (3M™ ESPE™ RAMITEC™) (Figure 2), and BA bite registration material (LuxaBite™ Bisacryl Registration Material) (Figure 3).

A total of 90 samples were prepared, which comprises 30 samples from each bite registration material. The specimens from each bite registration material were subdivided into three subgroups with ten specimens (n=10) in each used to evaluate tear strength, compressive resistance, and surface hardness, respectively.

2.1 Preparation specimens to evaluate tear strength (TS)

Dumbbell-shaped aluminium metal jigs were fabricated with 2mm in thickness, 80mm in length, a width of 5mm (periphery) and 3mm (centre) as per ASTM638. The jigs were then placed in the dental flask filled with dental stone to form moulds. The selected bite registration materials were mixed as per the manufacturer's instructions and packed into the mould. Care was taken to prevent air entrapment into the prepared samples. The set material (Figure 4) was then retrieved and stored in a container for further testing.

2.2 Preparation of specimens to evaluate compressive resistance (CR), and surface hardness (SH)

A cylindrical hollow tube of internal diameter 10mm and length of 5mm was made. Both sides were kept open for easy retrieval of the samples after setting. Each die was coated with a lubricating agent for ease of removal of set materials. The materials were mixed and packed into the mould and covered by two metallic plates for uniform distribution of pressure. The set material (Figure 5) was then retrieved and stored in a container for further testing.

2.3 Evaluation of tear strength

The dumbbell-shaped specimens from each material group were subjected to a tensile stress using the universal testing machine (Mecmesin Multitest 10i, United Kingdom) at a crosshead speed of 5mm/min.

Figures 1—3. Bite registration materials used in the study.
Where 1. Polyvinyl siloxane 2. Polyether and 3. Bis-acrylate.

Figure 4. Dumbbell-shaped specimens for evaluating tear strength.
Figure 5. Cylindrical-shaped specimens for evaluating compressive resistance, and surface hardness.

The load at which tear occurred was recorded. Tear Strength was calculated using the formulae:

TS (MPa) = F/A.

Where, F is the force magnitude at rupture, and A is the cross-sectional area of unstrained samples (mm^2).

2.4 Evaluation of compressive resistance

The cylindrical specimens (n=10) from each material group were subjected to the Compressive Resistance test using a Universal Testing Machine (UTM). A constant increasing load was applied until the specimen started deforming. The compressive resistance was recorded from the apparatus.

2.5 Evaluation of Surface hardness

The remaining ten cylindrical specimens (n=10) from each material group were tested for SH using a Vickers microhardness tester (FM-110Series, Japan). A load of 2.0kg force for 5 seconds was applied, and the indentations were made on the surface of each sample. The lens was focussed, and the length of diagonals was measured. The average length of the diagonals was considered as the surface hardness of the specimens.

The obtained data were subjected to statistical analysis using SPSS 16.0 version (Chicago, Inc., USA). All the study variables were tested for normal distribution by using the Kolomogrove test. The one way (ANOVA)/ Kruskal-Wallis test was used to compare study parameters among the groups. Tukey's post-hoc test was used for inter-group comparisons.

3. Results

The mean and standard deviation of all the tests are presented in table 1. Among the three materials tested, Bis-acrylate material showed the maximum tear strength followed by Polyvinyl siloxane. Polyether exhibited the greatest resistance to the compression followed by Bis-acrylate material. Bis-acrylate showed more surface hardness followed by polyether material (Table 1). The ANOVA showed a significant difference in tear strength (p=0.0001), compressive resistance (p=0.0001) and surface hardness (p=0.01) among three materials (Table 1).

The inter-group comparison (post-hoc analysis) showed significant differences (p=0.000) between the materials in compressive resistance and tear strength (Table 2). In surface hardness, a significant difference (p=0.000) was observed between polyvinyl siloxane and Bis-acrylate materials (Table 2).

Table 1: Comparison of tear strength, compressive resistance and surface hardness (One way ANOVA).

Groups	Tear strength (Mean±SD)	Significance (p-value)	Compressive strength (Mean±SD)	Significance (p-value)	Surface hardness (Mean±SD)	Significance (p-value)
Polyvinyl siloxane	37.51±13.45		4337.60±6562.49		4.76±0.45	
Bisacrylate	429.60±62.38	0.0001*	11955.39±2378.98	0.0001*	27.17±28.63	0.01*
Polyether	8.20±3.93		66960.09±14323.08		8.84±2.69	

* Statically significant differences

Table 2: Inter-group comparison (post-hoc analysis) of compressive resistance, tear strength, and surface hardness

Properties	Bite registration materials		Mean Difference ± Standard error	Significance (p-value)
Compressive resistance	Poly vinyl siloxane	Polyether	63294.56±3185.77	0.000
		Bis-acrylate	12013.83±3185.77	0.000
	Polyether	Bis-acrylate	51280.73±3185.77	0.000
Tear strength	Poly vinyl siloxane	Polyether	31.00±6.78	0.000
		Bis-acrylate	385.09±6.78	0.000
	Polyether	Bis-acrylate	416.10±6.78	0.000
Surface hardness	Poly vinyl siloxane	Polyether	4.39±2.625	0.098
		Bis-acrylate	14.58±2.625	0.000
	Polyether	Bis-acrylate	10.19667±2.625	0.000

4. Discussion

Oral rehabilitation involves a series of sequential steps that must be followed very judiciously to obtain the desired results [9]. The success of any prosthetic rehabilitation depends on various aspects related to the precise mounting of casts in an articulator. An accurate interocclusal record transfer is required for occlusal quality and the essential fabrication of a prosthetic restoration [10]. The degree of accuracy of the record between the articulator and the patient depends on the type of articulator, biologic factors and the recording material. In cases where the number of teeth present are satisfactory and will provide cast stability, the casts can be mounted by manual articulation. On the other hand, when large edentulous spaces are present, cast mounting is considerably more complex. It increases the need for accurate transfer of the interocclusal relationship and vertical dimension [9].

The 3D maxillomandibular relationship depends not only on the facebow and articulator but also on the recording material [11]. There are various methods of recording maxillomandibular relationships, viz, graphic, functional, cephalometric and direct interocclusal recordings. Direct interocclusal records are most commonly used to record maxillomandibular relationships because of their simplicity [1]. A recording medium is necessary to register the patient's inter-arch relationship. Some of the critical requirements of interocclusal materials include limited initial resistance to closure to avoid the displacement of periodontally compromised teeth or the mandible during record-making, dimensional stability, resistance to compression, ease of manipulation, biocompatibility, accurate recording and ease of verification.

Studies conducted previously stated that wax and ZOE are not reliable as interocclusal records because of significant linear changes. There can be mounting inaccuracies if not used immediately [12]. The various drawbacks of commonly used materials like dental waxes, dental plaster and ZOE include distortion,

compression and tearing. The flowability and flexibility of Polyether are significantly less, making it a stiff material easily subjected to breakage. On the other hand, polyvinylsiloxane undergoes shrinkage due to the loss of by-products, leading to questionable dimensional stability; however, its accuracy has been studied to be the best [2].

The present study encompassed three commonly used bite registration media, namely Polyether, polyvinylsiloxane and bis-acrylate. Each material was tested for Tear Strength, Compressive Resistance and Surface Hardness. Co-relation studies were done to compare the properties and find the one with the least distortion.

Bite registration materials should resist tearing when tensile stresses are applied during removal of the record and mounted cast separation. They are most susceptible to tearing in the interproximal areas. Tear in the bite record causes defects, will affect the accuracy of the final restoration. Additionally, some record material remnants in the interdental area may precipitate inflammation. Therefore, impression materials must have maximum tear Strength at the time of removal [8].

In this study, Bis-acrylate material displayed the maximum tear strength followed by Polyvinyl siloxane (Table 1). The reason for the high TS in Bis-acrylate is possibly the highly-dense polymer structure, which permits the material to resist tearing forces.

An ideal bite registering material should have high compressive resistance to prevent distortion caused by handling or processing. In the present study, Polyether bite registration material exhibited more resistance to compression compared to the remaining two materials (Table 1). The probable reason for the greater CR could be its low dimensional changes compared to other bite registration materials [16].

The hardness of a bite registration material after setting is critical, as it can ensure a distortion-free interocclusal recording. A hard, highly filled interocclusal bite registering material is expected to exhibit fewer vertical discrepancies due to reduced setting shrinkage and high resistance to deformation, thereby ensuring a more accurate fit on stone models [13]. In this study, Bis-acrylates exhibited the greatest surface hardness compared to PVS and PE materials (Table 1). This can be attributed to the presence of maximum fillers in the Bis-acrylate materials.

The conversion of carbon double bonds causes immediate shrinkage in a polymer. For each monomer segment of the chain, the larger Vander Waals intermolecular spacing is replaced by smaller intramolecular covalent bonds, resulting in changes in dimension and density [14]. Bis-acryl composite was introduced to overcome these negatives of methacrylate. Bisacryl composite consists of bi-functional substrates to provide cross-linkage with one another and form monomer chain cross-linkage, leading to increased impact strength and toughness. They also contain inorganic fillers to increase their abrasion resistance. They have low polymerisation shrinkage, low exothermic reaction, reduced tissue toxicity, good wear resistance and strength. But these materials are expensive, brittle and some show allergic reactions.

Bis-acrylate (LuxaBite) can be considered the bite registration material of choice. It showed a higher degree of stiffness, adequate compressive resistance, and highest tear strength than any other available material.

The present study evaluated and compared the tear TS, CR and SH of only three commercially available interocclusal bite registration materials. In addition, this is an in vitro study and cannot reflect the conditions of clinical applications exactly. Therefore, further studies may be focused on evaluating the other critical physical and mechanical properties of different materials of various brands in clinical situations.

5. Conclusion

Within the limitation of this in-vitro study, the following conclusions can be drawn.

- Bis-acrylate was found to have the maximum tear strength and surface hardness.
- Polyether was examined to have the highest compressive resistance.
- Polyvinylsiloxane showed median values for all three properties (surface hardness, compressive resistance and tear strength).
- Case specificity and necessary precautions to overcome the drawbacks of each material plays an integral role in the choice of the bite registration medium in order to achieve accurate results.

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