ORIGINAL RESEARCH

Evaluating Cost-effectiveness and Mixing Efficacy for Elastomeric and Temporary Restorative Material Using Two Mixing Tips: A SEM-EDS Analysis

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Received on: 03 August 2024; *Accepted* on: 01 October 2024; *Published on*: 20 December 2024

Abstract

Aim: This study aimed to compare the mixing efficacy and cost-effectiveness of new T-mixer tips against the standard double helical tips for a light-body elastomeric impression and a temporary/interim restorative material using a scanning electron microscope (SEM) and energy-dispersive X-ray spectroscopy.

Methodology: Automixed samples ($n = 16$) were divided into four groups of four samples each: Samples that were mixed with Helical tip for elastomer, T-mixer tip for elastomer, Helical tip for interim restorative material, and T-mixer tip for interim restorative material. These samples were then evaluated for SEM analysis. Energy dispersive spectroscopy (EDS) analysis was conducted on three random surface spots and two cross-section spots. Tests for detail reproduction using ADA Specification 19 die and surface roughness using a stylus were also performed. Data were recorded and statistically analyzed. (Kindly mention whether the details of reproduction and surface roughness for all the groups are considered. Also, explain what factors SEM and EDS evaluate that contribute to the evaluation of mixing efficiency).

Results: For elastomer surface sample EDS analysis, the p-values were 0.180 (carbon) and 0.065 (silicone). Cross-section samples showed p-values of 0.343 (carbon and silicone). For temporary restorative material EDS analysis, surface p-values were 0.180 (carbon) and 0.394 (silicone), and cross-section p-values were 0.886 (carbon) and 0.686 (silicone). The groups mixed using T-mixer tips showed no change in the mixing efficacy as compared to the group mixed using helical tips for both materials. The p-values for cost-effectiveness were 0.021 for both elastomeric and Protemp temporary restorative material. The groups mixed using T-mixer tips saved more material than groups mixed using the helical tip.

Conclusion: There is no significant difference in the mixing efficacy between T-mixer and helical tips for both materials. However, T-mixer tips are more cost-effective than helical tips.

Clinical significance: The present study would help clinicians make a better choice of selecting the mixing tips when it comes to function as well as cost. The new T-mixer tips are proven to provide a better solution compared to helical tips, which not only would save the clinicians' cost of impression materials and interim restorative materials but also render the same homogeneity as that of the helical tips. The electron microscopic analysis provided a better insight into the homogeneity and hence the mixing efficacy of the samples. The detail reproduction and surface roughness were some additional parameters that weren't a part of the original study model. They were included for the addition of credibility to the conducted study and provided adjunctive results to those obtained by SEM and EDAX analysis.

Keywords: Automixing tips, Cost-effectiveness, Detail reproduction, Impression material, Surface roughness, Temporization.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3728

Introduction

Though modern dental practice has led to the advent of newer technologies including the use of intra-oral scanners, yet conventional impression procedures are used as a standard practice in many dental setups. The use of polyvinyl siloxane (PVS) impression material in fixed prosthodontics is paramount due to numerous advantages like superior dimensional accuracy, good dimensional stability, and the absence of by-products.[1] According to a study conducted by Ud Din et al, under dry conditions, all commercial and Exp VPS produced the 20 µm line satisfactorily.[2]

According to GPT 9, temporization or provisionalization is defined as "to establish esthetics, occlusal stability and function for a limited time in preparation for the definitive prosthesis; to verify therapeutic outcome and patient acceptance before the definitive prostheses."[3]

Out of many provisionalization options, the most commonly employed ones include the use of bis-acryl resins that provide an efficient way of fabricating chairside temporary crowns and bridges. Compared to PMMA and PEMA, they provide superior mechanical qualities, reduced polymerization shrinkage, a less exothermic process, long-term color stability, and a certain amount of stiffness.[4]

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How to cite this article: Bhave RP, Sabane AV, Vijayaraghavan V, *et al*. Evaluating Cost-effectiveness and Mixing Efficacy for Elastomeric and Temporary Restorative Material Using Two Mixing Tips: A SEM-EDS Analysis. J Contemp Dent Pract 2024;25(9):885–890.

Source of support: Nil

Conflict of interest: None

Both these materials are supplied as a base and a catalyst in a two-paste form that are mixed chemically to form a set product used for their respective purposes. Homogenous mixing of these materials is extremely important since a heterogeneous mix would obviously result in poor rendering of the material characteristics and result in an inaccurate impression or the interim prosthesis due to air incorporation.[4]

Various mixing techniques are used for the effective mixing of the base and the catalyst paste. They include mechanical mixing using a mixing spatula by hand, static mixing using a two-cylinder cartilage and a gun with a mixing tip, and dynamic mixing using motor and parallel plungers.

Static mixing shortens the mixing time, produces fewer voids in the mix, and improves uniformity in proportioning and mixing. Furthermore, the likelihood of material contamination is reduced. Making sure the tube holes that disseminate the pastes stay unclogged is one precaution that should be considered while utilizing these automixing machines. Expressing a tiny amount of material from the cartridge prior to attaching the mixing tip can help prevent issues. Additionally, this kind of apparatus has been modified to blend and administer temporary cements and acrylic materials for crowns and bridges.

There are several different commercially available mixing tips on the market. One such company is Medmix which created the MIXPAC "T-mixer," a revolutionary mixing tip design that minimizes material waste.[5] The manufacturing company states that compared to standard helical mixing tips, the newly engineered T-mixer tips save around 40% of the material. It is unclear, though, if the homogeneity of elastomeric impression materials treated with such mixing tips is superior than that of traditional helical ones.

Scanning electron microscope and energy dispersive X-ray spectroscopy are the tests usually carried out to assess the elemental composition of the mixed materials at those points which would aid in evaluation of the homogeneity of the materials under study.[6]

The most routinely used dental materials in contemporary fixed prosthodontics and implant prosthodontics are additional silicone impression materials and bisacryl-based interim restorative material. However, very little data is available that actually tests the mixing efficacy and hence, the homogeneity of the set materials. The current study was designed to primarily compare and evaluate the mixing efficacy and cost-effectiveness of the new T-mixer tips against the standard double helical tips using SEM and energy-dispersive X-ray spectroscopy. The electron microscopy images (SEM images) provided a qualitative analysis of the materials under study for any heterogeneities, unmixed catalysts, or voids. The EDS analysis of the SEM image gave the elemental composition of the mixed materials at those points that evaluated the mixing efficacy at the elemental level.

Also, the surface reproducibility of the impression material and surface roughness of the interim restorative material were evaluated as adjunctive tests to further support the objectives of the present study.

Methodology

The current study was conducted at Bharati Vidyapeeth Dental College and Hospital, Pune, India from January 25, 2024, to May 29, 2024. The institutional research committee approval was obtained on 27 June 2022. The SEM samples were analyzed at the National Chemical Laboratory, Pune, and the weight analysis was carried out at PRAJ Dental Laboratory, Pune.

For SEM and EDS analysis, 16 Auto mixed samples were divided into four groups ($n = 4$) each based on the type of mixing tip and the restorative material according to the manufacturer instructions:

- Samples that were mixed with Helical tip for elastomeric impression material (Express™ XT Light Body).
- Samples that were mixed with T-mixer tip for elastomeric impression material (Express™ XT Light Body).
- Samples that were mixed Helical tip for interim restorative material (3M™ Protemp™ 4).
- Samples that were mixed T-mixer tip for interim restorative material (3M™ Protemp™ 4).

Tests for detail reproduction using ADA Specification 19 die and surface roughness using a stylus were also performed as supportive or adjunctive tests.

SEM and EDS Analysis

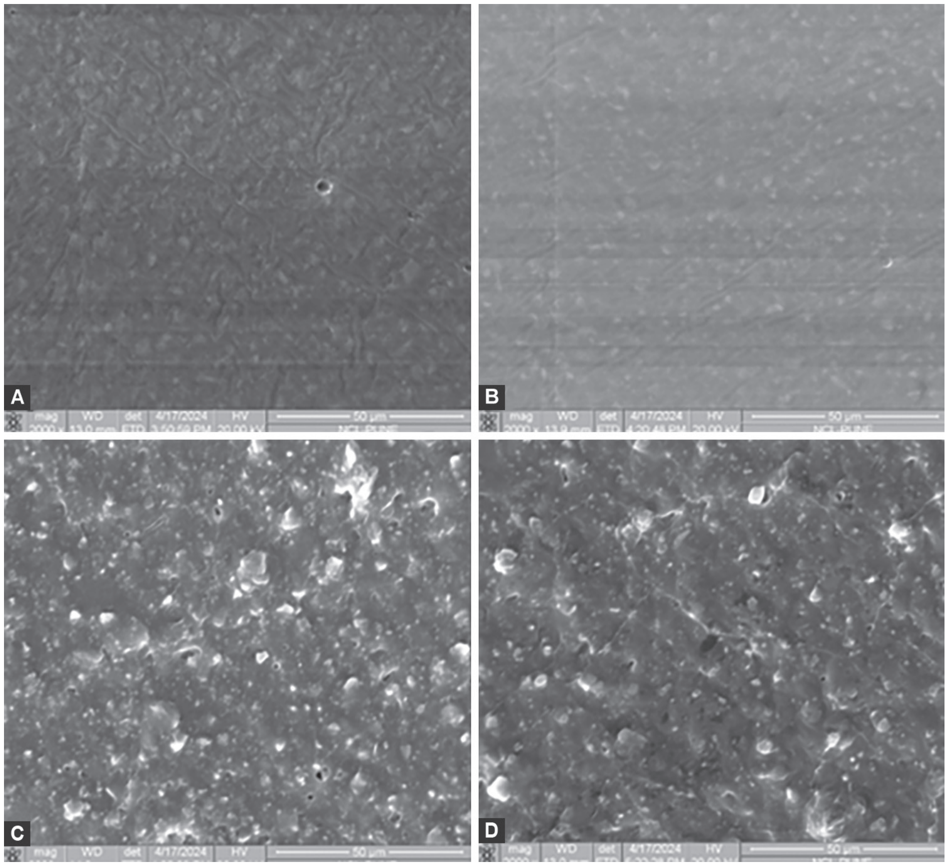
Four samples from each group, comprising of total 16 samples were evaluated for SEM analysis. While the samples for the elastomeric impression materials were divided as L1 dispensed with the helical tip and L2 dispensed with the "T-mixer" tip (yellow collar), the samples for interim restorative material were divided as P1 dispensed with the helical tip and P2 dispensed with the "T-mixer" tip (blue collar). From each tip, the respective material was dispensed on an acetone-cleaned and dried glass slab. The other clean glass slab was put on the dispensed material and was kept for 3 minutes more than the normal expected setting time, that is, 8 minutes for elastomeric impression material and 8 minutes for interim restorative material. The materials were carefully removed only from the borders with a clean pair of tweezers and put on the surface stub with a carbon tape. For the cross-section, a cross-section stub was used and the samples were secured firmly with the help of a carbon tape. Two samples from each group were evaluated for the cross-section analysis. Gold coating of the non-conductive sample was done using a gold sputter.

These samples were then evaluated by SEM analysis. The ED analysis was done on three random surface spots and two cross-section spots. The electron microscope used for this analysis was model FEI, Environmental Scanning Electron Microscope, FEI Quanta 200-3D. The stubs were arranged in the gold sputter coater and were sprayed with an acceleration voltage of (20 KV) for 120 seconds. The mode of analysis was high vacuum. Each sample was viewed under 250×, 500×, 1000×, 2000×, and 5000× magnification and the surface morphology was analyzed carefully at each magnification to notice any surface heterogeneities. Less the heterogeneities, the more the mixing efficacy of the material.

An EDS analysis (kindly mention the trade name and how were the reading obtained, e.g., graph) was carried out on three random spots on the surface and two random spots on the cross-section samples. The weight of silicone and carbon that formed the major part of the product was evaluated at these points.

Detail Reproduction

For the evaluation of detail of reproduction carried out for only the elastomeric impression material alone, an apparatus consisting of three parts: A test block, ring, and a metal plate all made of stainless steel according to ADA specification 19 with an outer diameter of 38 mm, internal diameter of 29.97 mm, and thickness of 3.5 mm



Figs 1A to D: (A and C) Surface and cross-section with helical tip for elastomeric material, respectively; (B and D) Surface and cross-section with T-mixer tip for elastomeric material, respectively

was considered. Three vertical lines of thickness 75, 50, and 20 micrometers were scribed and separated by two horizontal lines of 25 mm on the test block. A total of four samples mixed using helical and T- Mixer tips from each group of elastomeric impression material were fabricated and evaluated. The stainless steel ring was placed onto the test block. Impression material was syringed on the mold using the selected sample tip in an auto-mixing gun and the plate was then covered over the mold using a polyethylene sheet in between. The excess impression material was extruded out of the mold and a standardized pressure of 5 N was applied. The assembly was transferred into a water bath 32 ± 2 °C. Eight minutes later, (3 minutes post-setting time), the samples were removed. The 20-micrometer vertical line was checked for the detail reproduction in between the 25 mm horizontal lines under Stereo Microscope (Wuzhou New Found Instrument Co. Ltd. China, Model: XTL 3400E) under 10× magnification.

Evaluation of Surface Roughness (RA) for Interim Restorative Material

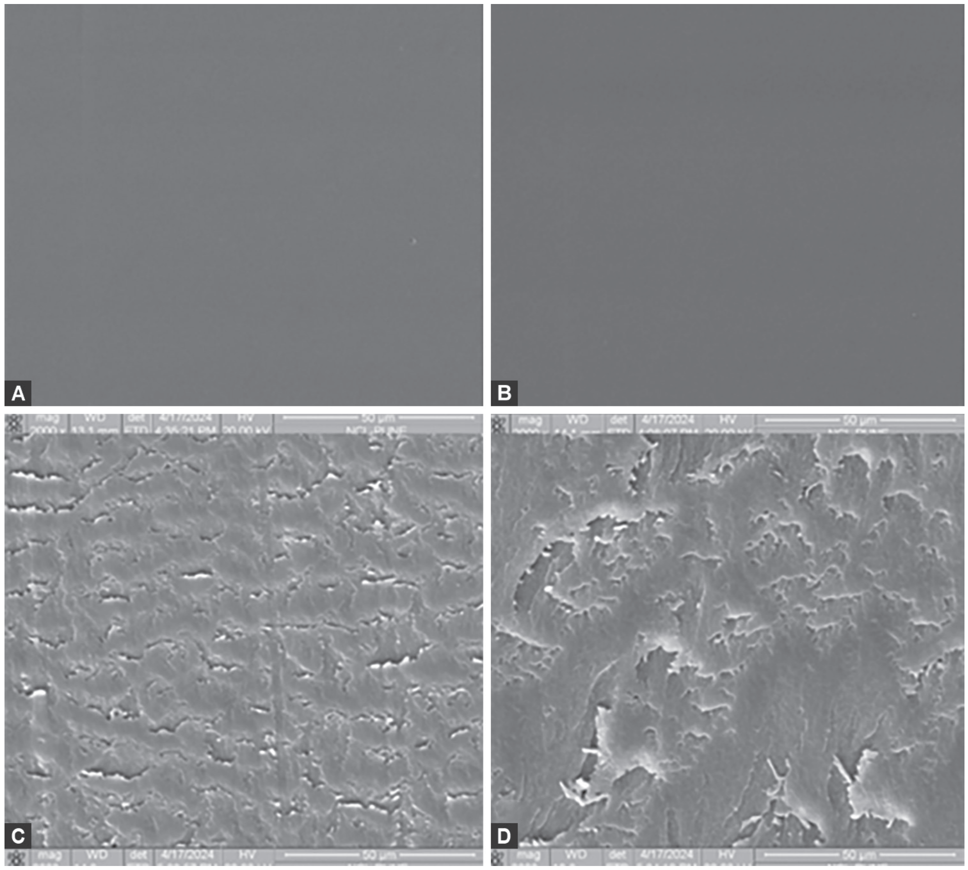
The interim restorative material samples were evaluated alone. The interim restorative group samples were prepared with the same procedure as that for SEM analysis. A total of four samples from both groups were evaluated. The evaluation was carried out by running a stylus to evaluate the roughness of the material in micrometers (Surface Roughness Tester, Mitutoyo, Japan, Model: SJ 210) at a speed of 0.5 mm/s with a cut-off length 4 mm. The surface roughness measures the microscopic ups and downs of a particular surface calculated as surface height deviations.

Evaluation of Cost-effectiveness

The unfilled helical as well as “T-mixer” tips for both materials were weighed separately using a precision balance (LWL Germany, Model: LB-210S, Accuracy: 0.0001 gm). A total of four samples from each group were evaluated. After mixing the materials in the tips, a bp blade of 15 no. was used to cut the excess set material oozing out from the tips, and the filled tips were weighed again separately using the precision balance. The difference in the filled and unfilled weights of the tip was analyzed for material wastage.

Results

Upon 2000× and 4000× magnification (Figs 1 and 2), the surface samples in the groups for elastomeric impression material from both helical as well as T-mixer revealed a “smooth, wrinkled surface.” Heterogeneities were not found in any of the samples indicating an evenly mixed sample throughout. The cross-section images showed a smooth surface along with some minute porosities indicating air incorporation for the tips for both groups. The surface images of the interim restoration sample also revealed a “smooth surface without heterogeneities” for both tips. The cross-section images showed a clearer surface with minute porosities indicating minor air entrapments while mixing for samples for both tips indicating no difference in the mixing efficacy upon SEM analysis. The results for the groups of PVS elastomer samples for surface samples showed a p-value of 0.180 and 0.065 for the weights of carbon and silicone respectively, while the cross-section samples show a p-value of 0.343 for the weight of both carbon and silicone. For the interim



Figs 2A to D: (A and C) Surface and cross-section with helical tip for Interim restorative material, respectively; (B and D) Surface and coss-section with T-mixer tip for Interim restorative material, respectively

restorative material, the *p*-values for surface energy dispersive spectroscopy (EDS) were 0.180 and 0.394 for the weights of carbon and silicone, respectively. For cross-section, the *p*-values for carbon and silicone weights were 0.886 and 0.686, respectively.

The detail reproduction test performed on the elastomer samples demonstrated a well-defined continuous line of 20 micrometers for the entire 25 mm for all the samples of both helical and T-mixer groups when evaluated under a stereomicroscope.

The surface roughness tests indicated that the surface is smoother with the samples when mixed with the T-mixer tips. The *p*-value for the same is 0.021 indicating a difference in the surface roughness. The surface roughness of interim restorative material when used with the T-mixer tips was found to be 88.16% less than when used with the helical tips (Table 1).

Table 1: EDAX values of samples assessed

Material	*Light body (%Weight)*	*Protemp (% Weight)*
Helical tip		
Surface	C = 11.91%	C = 32.97%
	Si = 69.97%	Si = 39.83%
Cross-section	C = 8.34%	C = 30.01%
	Si = 75.40%	Si = 44.32%
T-mixer tip		
Surface	C = 13.92%	C = 31.08%
	Si = 64.33%	Si = 41.41%
Cross-section	C = 3.15%	C = 30.71%
	Si = 81.90%	Si = 42.71%

C, amount of carbon in %wgt; Si, amount of silicone in %wgt

Statistical Analysis

Method of statistical data analysis: SPSS version 20 will be used for analyzing the data. All quantitative data will be tabulated using means and standard deviations. Comparison among the groups will be done using the Student *t*-test (if the data is parametric) and Mann–Whitney *U* test (if the data is non-parametric). *p*-values less than or equal to 0.05 will be considered statistically significant (Tables 2 to 5).

Discussion

The present study aimed primarily to evaluate the mixing efficacy and cost-effectiveness of auto-mixing gun tips for routinely used dental materials in regular clinical practice. The objectives of conducting such a study were to compare the homogeneity of the mixed samples and the amount of material wasted in each helical tip that would ultimately help us understand the mixing efficacy and cost-effectiveness respectively. The purpose of this study was to help clinicians to choose the tips that would lead to less material waste and deliver uniformly mixed dental materials. The most routinely used dental materials in contemporary fixed prosthodontics and implant prosthodontics are addition silicone impression materials and bisacryl-based interim restorative material. Hence, the materials selected for this study were Express™ XT Light

Table 2: Mean and standard deviation of surface and cross-section SEM-EDX values light body of PVS impression materials tested for different mixing tips

	%Weight of element CK	*%Weight of element SiK*
Groups (Mixing tips)	*Mean ± SD*	*Mean ± SD*
Long tip (L1) surface	11.92 ± 2.07	70.07 ± 2.40
Short tip (L2) surface	13.92 ± 5.09	64.33 ± 7.59
p-value (Mann–Whitney *U* test)	0.180	0.065
Long tip (L1) cross-section	8.34 ± 5.90	75.39 ± 13.58
Short tip (L2) cross-section	3.15 ± 3.32	81.89 ± 3.67

Table 3: Mean and standard deviation of surface and cross-section SEM-EDX values of protemp temporization materials tested for different mixing tips

	%Weight of element CK	*%Weight of element SiK*
Groups (Mixing tips)	*Mean ± SD*	*Mean ± SD*
Long tip (P1) surface	32.97 ± 2.88	39.83 ± 2.79
Short tip (P2) surface	31.06 ± 2.12	41.41 ± 2.53
p-value (Mann-Whitney *U* test)	0.180	0.394
Long tip (P1) cross-section	30.01 ± 7.51	44.32 ± 11.93
Short tip (P2) cross-section	30.70 ± 9.17	42.71 ± 15.11
p-value (Mann–Whitney *U* test)	0.886	0.686

Table 4: Mean and standard deviation waste (g) of light body PVS elastomeric impression materials and protemp interim restorative material as per mixing tips

Groups (Mixing tips)	*Mean*	*Standard deviation*	*Percentage difference*
Long tip (L1) light body	1.1472	0.0049	31.40%
Short tip (L2) light body	0.7870	0.0296	
p-value (Mann–Whitney *U* test)	0.021*		
Long tip (P1) Protemp	0.8024	0.0186	22.33%
Short tip (P2) Protemp	0.6232	0.0072	
p-value (Mann–Whitney *U* test)	0.021*		

**p*-value is statistically significant.

Table 5: Mean and standard deviation of surface roughness of protemp temporization materials as per mixing tips

Groups (Mixing tips)	*Mean*	*Standard deviation*	*Percentage difference*
Long tip (P1)	0.2830	0.0904	88.16%
Short tip (P2)	0.0335	0.0056	
p-value (Mann–Whitney *U* test)	0.021*		

Body impression material (addition silicone elastomeric impression material) and 3M™ Protemp™ 4 interim restorative material (bisacryl-based temporary restorative material) used widely worldwide by clinicians. There are several different commercially available mixing tips on the market. One such company that is used in addition to the standard helical tips is Mixpac's T-mixer tips which claimed to reduce the material waste due to its shorter length. The materials mixed using the shorter length tips should be effectively mixed as that of the helical tips to render ideal homogenous properties of the material mixed. The other tip used for comparison was the standard helical tip used routinely which is longer than the T-mixer tips. The materials used in comparing the helical and T-mixer tips were kept the same since the comparison was between the tips and not between commercially available alternative options for either impressions or provisionalisation.[7,8]

The current study used a SEM to understand and evaluate and compare the minute surface topographic details, and surface heterogeneities in the mixed samples. Additionally, EDS done on these SEM samples at three widely spaced points helped us evaluate the homogeneity of the sample at a microscopic chemical level. Silicone and carbon being the elements of comparison since silicone formed the primary backbone element and carbon was present in the product of both samples.

Energy dispersive spectroscopy has several benefits such as: elemental coverage for all but the lightest elements (carbon and above are detectable, boron is troublesome); quantitative elemental data; and the capacity to scan elements; a broad spatial range from roughly 1 mm to submicron; areas (raster scanning) and single spots; elemental spectra are connected to image data produced by electron microscope; The data can be used to create elemental maps, or "dot maps"; Although generated data are only from the top few microns of the material under investigation (surface sensitive), many believe this to be a destructive technique, especially when it comes to electronic components. Depth information can be obtained using variable excitation voltages and modeling programs like Monte Carlo.[9]

The cross-section images showed a clearer surface with minute porosities indicating minor air entrapments while mixing for samples for both tips indicating no difference in the mixing efficacy upon SEM analysis.

In a study conducted by Ud Din et al, the elastomeric material's most concentrated component was silicon (Si). Generally speaking, every material had the same makeup, an all-Si compound in existence. Zinc (Zn), Si, Calcium (Ca), and Indium (I) were the materials that Clonage Putty offered. Zn, Magnesium (Mg), Si, and Sodium (Na) were presented by Optosil P. Confort. Antimony (Sb), Germanium (Ge), Aluminum (Al), Si, Ca, and Zn were offered by Impregum Soft and Reprosil A+.

It was observed that there is no statistical difference in the mixing efficacy of both helical and T-mixer tips when evaluated under SEM and EDAX. These results were further supported by the adjunctive tests–detail reproduction tests done on the elastomer tips sample and surface roughness evaluation done on the interim restoration samples.

The surface roughness of interim restorative material when used with the T-mixer tips was found to be 88.16% less than when used with the helical tips. This would signify that there would be less plaque accumulation when the T-mixer tips are used against the conventional helical tips.

The studies carried out by Schwantz et al. indicate that Protemp 4 has smaller particles than the other bis-acryl composite resins, according to the SEM examination, and these fillers are probably silica nanoparticles. Nanoparticles are likely utilized to boost surface shine and smoothness as well as esthetics.[10]

The *p*-values for demonstrating the cost-effectiveness were as follows: 0.021 for both light body PVS material and Protemp temporization material.

Both these values are statistically significant and hence, it can be said that the T-mixer tips provide a better cost-effective solution than the helical tips.

In the present study, it was also found that 31.40% of the light body elastomer and 22.33% of the interim restorative material were saved.

In a study carried out by Ana Terese et al., it was found that 24% of virtual monophase and 30% of Panasil light impression material was saved in the T-mixer tips.[11]

The major limitation of the present study model is that this study followed an *in vitro* setup. Due to this major disadvantage, all the results obtained in the present study cannot be conveniently extrapolated into the general clinical scenarios where other factors like effective moisture control, efficacious gingival retraction, and other operator-related factors come into play. When using SEM analysis, the size and cost are the drawbacks. The cost of operating SEM is high. Artifacts may arise from sample preparation. The fact that SEM can only be used on solid, inorganic materials that are tiny enough to fit inside a vacuum chamber with a reasonable vacuum pressure is a significant drawback. Only a part of an entire sample is viewed under a SEM, hence it may not provide extremely accurate results. A few drawbacks of EDS were noted. The difficulty of evaluating bulk sections of the material and relatively non-sensitivity of the method with lower detection in the percentage range were some noteworthy drawbacks. The parameters chosen for the supplementary tests were purely based on clinical relevance-the detail reproduction was used for the elastomeric impression materials since its use is largely concerned with making accurate impressions, surface roughness analysis was done on the interim restorative material since a smooth surface temporary restorative material is considered important for tissue health as well as plaque control of the interim restorative material. Both these parameters evaluated, are a function of the mixing efficacy of two materials and provide a better understanding of the clinical relevance of the homogenously mixed samples. Further, the study does not analyze the use of different impression materials and interim restorative materials available in the market.[12–15]

Further studies need to be done in order to evaluate the effectiveness of these tips against various commercially available alternative products.

Conclusion

According to the tests conducted, "T-mixer" tips and helical mixing tips show no difference in the homogeneity, and the weight analysis shows that the "T-mixer" tips save material than the helical mixing tips. This signifies that the "T-mixer" tips are more cost-effective than the conventional helical mixing tips for both—elastomeric and temporary restorative material. There is no difference in the mixing efficacy of the "T- Mixer" tips as compared to the helical mixing tips for both—elastomeric and temporary restorative material.

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