Desired retrievability of cemented implant-supported fixed prosthesis makes the retentive strength of cementing agents an important consideration. The aim of the study was to evaluate the retentiveness of purposely designed implant cement and compare its retentiveness with dental cements that are commonly used with implant systems. Ten implant analogs were embedded in auto-polymerizing acrylic resin blocks and titanium abutments were attached to them. Fifty standardized copings were waxed directly on the abutment and casted. The cements used were: (1) resin-bonded zinc oxide eugenol cement, (2) purposely designed implant cement, (3) zinc phosphate cement, (4) zinc polycarboxylate cement, and (5) glass ionomer cement. After cementation, each sample was subjected to a pull-out test using universal testing machine and loads required to remove the crowns were recorded. The mean values and standard deviations of cement failure loads were analyzed using ANOVA and Bonferroni test. The mean values (± SD) of loads at failure (n = 10) for various cements were as follows (N): resin-bonded zinc oxide eugenol cement 394.62 (± 9.76), Premier implant cement 333.86 (± 18.91), zinc phosphate cement 629.30 (± 20.65), zinc polycarboxylate cement 810.08 (± 11.52), and glass ionomer cement 750.17 (± 13.78). The results do not suggest that one cement type is better than another, but they do provide a ranking order of the cements regarding their ability to retain the prosthesis and facilitate easy retrievability.

Key Words: cement failure load, dental cement, implant supported prosthesis, retentive strength and retrievability

INTRODUCTION

Fixed implant-supported restorations are an established treatment option for replacing missing teeth. It may be required to retrieve the implant supported prostheses in the event of a biologic or technical complication.1–7 These complications are relatively common,8,9 even in the hands of experienced clinician.10–14 Therefore, retrievability of implant prosthetic component is a significant safety factor.15 Retrieval of the prostheses may be necessitated by screw loosening, fracture of screw, fracture of abutment, repair or replacement of prosthesis, modification of prosthesis after loss of an implant in case of multiple implant restoration, and surgical intervention. It should also be noted that removal of implant-supported restoration is sometimes needed for better evaluation of oral hygiene. Peri-implant probing is more accurate if prosthesis is removed.15,16

Fixed implant supported restorations are either cemented or screw-retained on the implant abutments. Several arguments, both for and against these two possible ways of fixation, can be found.1 However, there is no consensus as to whether one
method of retention is superior over another,\textsuperscript{3} but cemented restorations seem to gain more popularity because of a lower complication rate\textsuperscript{17} and a higher fracture resistance of the veneering ceramic.\textsuperscript{18} Still, many practitioners do not consider cement retention as an option in implant-supported prostheses because they believe that cemented prostheses are not retrievable.\textsuperscript{19}

This conundrum naturally focuses attention on the choice of cement. On one hand, selection of a cement that is too retentive could lead to damage of restoration or implant and its abutment due to aggressive removal techniques; on the other hand, the selection of a cement that is not retentive enough could be a potential source of embarrassment for the patient.\textsuperscript{20} As a result, practitioners who desire retrievability have generally gravitated toward using cements with submaximal retentive properties.\textsuperscript{19}

At present, the majority of cements used in implant dentistry have been designed for use with prostheses cemented to natural teeth.\textsuperscript{9} Of late, there is introduction of cements specifically formulated for this purpose, and manufacturers claim several advantages. However, very few studies have been conducted on specifically designed implant cement. The purpose of this study was to evaluate the cement failure load (CFL) of specifically designed implant cement and to compare its cement failure load with that of dental cements commonly used with implant systems.

\textbf{MATERIAL AND METHODS}

Ten implant analogs and 10 implant abutments for EZ Hi-Tec Internal Hex Implant of Diameter 4.2 mm (Lifecare Devices Pvt Ltd, Mumbai, India) were used. Nine implant analogs were mounted in individual auto-polymerizing acrylic resin (DPI-RR Cold Cure, Mumbai, India) block (2.9 cm $\times$ 1.4 cm) using a dental surveyor. A titanium abutment was placed on each implant analog and torqued at 35 Ncm using a torque wrench (Lifecare). The occlusal access opening and the screw-thread of the abutments were filled with modeling wax before cementation.

One implant analog was mounted into a block of auto-polymerizing acrylic resin block of 3 cm $\times$ 3 cm. A master coping of auto-polymerizing acrylic resin was constructed to make a mold of the master coping with elastomeric impression material (Aquasil, Dentsply, York, Pa).

With the help of this silicone mold, 50 standardized copings were waxed (BEGO, Bremen, Germany) directly onto the unmodified abutment and sprued (Figure 1). The sprue had a minimum of 15 mm length and was parallel to the line of draw of the coping, to be later used as the mechanism of attaching the metal coping to the universal testing machine crosshead (Lloyd LR50K, Ametek, Berwyn, Pa). Finished wax patterns were invested (Bellasun, BEGO) and casted with Ni–Cr alloy (Wiron, BEGO). Fitting surfaces of metal copings were sandblasted with 50 $\mu$m aluminium oxide particles (Korox 50, BEGO) for 5 seconds. Each metal coping was examined at 3.75 $\times$ magnification for surface irregularities on the intaglio surface and seated on the abutment to evaluate marginal fit and complete seating of the coping on abutment under magnification (Figure 2). Then, intaglio surfaces of all the metal copings and the abutments surfaces were steam cleaned.

After all the metal copings were ready, the acrylic block (3 cm $\times$ 3 cm) with mounted implant analog–abutment assembly was trimmed to the size as that of other acrylic blocks, that is, 2.9 cm $\times$ 1.4 cm. The castings were randomly divided into five experimental groups, with each group consisting of 10 test specimens. The cements used in this study are listed in Table 1. All cements were mixed following the manufacturers’ instructions. The test specimens of each group were cemented with one of the five luting cements to be tested. Cements were applied on the axial surface of the copings with a brush to minimize hydrostatic pressure during seating. Copings were seated quickly on the abutment with hand pressure for 10 seconds. This was followed immediately by placement of a 5 kg load with help of cementation jig directed down the long axis of the sprue, maintained for 10 minutes, according to the ADA specification 96 (Figure 3). Specimens were examined visually to confirm complete seating of the coping onto the abutment, referenced by the absence of marginal space. After setting, excess cement was removed using Universal Implant Scaler.

After storing the implant analog–abutment–coping assemblies in physiological saline solution...
for 24 hours at a temperature of 37°C, the specimens were subjected to tensile loading until separation to determine the retentive strength. Acrylic blocks were gripped with lower tensile jig, and sprues of the copings were attached to the upper tensile jig (Figure 4). Tensile load was applied using 2000 N load cell at a constant crosshead speed of 0.5 mm/min until separation of the copings occurred (Figure 5). The loads at failure were recorded in Newtons.

Abutment surfaces were steam cleaned to remove the residual cement. Whenever necessary, remaining cement on abutment surfaces was removed with Universal Implant Scaler. Subsequent-

<table>
<thead>
<tr>
<th>Group</th>
<th>Cement</th>
<th>Type</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Kalzinol</td>
<td>Resin-bonded zinc oxide eugenol cement</td>
<td>DPI, India</td>
</tr>
<tr>
<td>II</td>
<td>Premier implant cement</td>
<td>Non-eugenol temporary resin cement</td>
<td>Premier Dental Products, Pa</td>
</tr>
<tr>
<td>III</td>
<td>De Trey Zinc</td>
<td>Zinc phosphate cement</td>
<td>Dentsply, Germany</td>
</tr>
<tr>
<td>IV</td>
<td>Poly-F</td>
<td>Zinc polycarboxylate cement</td>
<td>Dentsply, Germany</td>
</tr>
<tr>
<td>V</td>
<td>GC Gold Label</td>
<td>Glass ionomer luting cement</td>
<td>GC Corp, Japan</td>
</tr>
</tbody>
</table>
ly, all the test specimens of different groups of luting cements were subjected to testing.

**RESULTS**

The data comprises the maximum loads at failure expressed in Newton (N). A one-way ANOVA and multiple comparisons (post-hoc tests) using Bonferroni test was carried to find out among which pair of groups there existed a significant difference. Table 2 shows the sample size, means, standard deviations, minimums, and maximums of the cement failure loads for the different cements.

Higher mean cement failure load was recorded in zinc polycarboxylate cement, followed by glass ionomer cement. The next highest mean cement failure load was recorded in zinc phosphate cement, followed by resin-bonded zinc oxide eugenol cement. Premier implant cement recorded the lowest mean cement failure load. The difference in mean cement failure loads recorded in the different groups was found to be statistically significant ($P < 0.001$). Figure 6 shows the box plot of the cement failure loads for the various cements.

**DISCUSSION**

The proper handling of cement-retained implant-supported prosthesis can provide retrievability without compromising the occlusion, esthetics, and stress distribution to the prosthetic components and bone–implant interface. Keeping the biological and technical failures inherent with implant-supported prosthesis in mind, one cannot fully justify permanently cementing an implant-supported prosthesis. According to Breeding et al, the type of cement is the deciding factor for retention if retrievability of the prosthesis is the issue.\(^{21}\) There are two main types of cements available for use in restorative dentistry: provisional and definitive.\(^ {22}\)

Definitive cements are not recommended for implant retention because they are too strong for retrievability.\(^ {23}\) The ideal taper of the implant abutment and the longer walls dictate the use of a provisional cement for long-term retention. This allows the operator to control the overall retention of restorations by using a weaker cement to offset the superior retentive features of the implant abutment.\(^ {24}\) The majority of cements used in implant dentistry at present have been designed for use with crowns luted to natural teeth. In cementing crowns to implant abutments, luting agents are required to act in a different manner to oppose two metallic surfaces.\(^ {20}\)

The group of cements tested in this study ranged from common dental cements generally designated for permanent cementation to those considered for provisional cementation. One cement specifically designed for implant-supported prostheses was also included. According to Jorgensen\(^ {25}\) and Kaufman,\(^ {26}\) several factors influence the retention form of conventional cement-retained prostheses. All the factors excluding the type of cement were standardized for all specimens during the investigation.

The results obtained in the study indicated that base metal copings cemented on titanium abutments with provisional cement (resin-bonded zinc oxide eugenol) were much less retentive than the copings cemented with definitive cements (zinc phosphate cement, glass ionomer cement, and zinc polycarboxylate cement). However, the Premier implant cement was least retentive. This present study is in agreement with the studies of Clayton et al,\(^ {27}\) Covey et al,\(^ {28}\) and Kent et al,\(^ {29}\) who found that CeraOne abutments cemented with permanent cement produced greater retention strengths than did provisional cement.

Zinc polycarboxylate cement had highest mean

<table>
<thead>
<tr>
<th>Cement</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Kalzinol)</td>
<td>10</td>
<td>394.62</td>
<td>9.76</td>
<td>381.00</td>
<td>410.20</td>
<td>1864.618</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Group II (Premier implant cement)</td>
<td>10</td>
<td>333.86</td>
<td>18.91</td>
<td>306.40</td>
<td>359.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III (De Trey Zinc)</td>
<td>10</td>
<td>629.30</td>
<td>20.65</td>
<td>595.70</td>
<td>653.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV (Poly-F)</td>
<td>10</td>
<td>810.08</td>
<td>11.52</td>
<td>794.00</td>
<td>827.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group V (G C Gold Label)</td>
<td>10</td>
<td>750.17</td>
<td>13.78</td>
<td>729.80</td>
<td>769.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CFL of all cements used in this study, and the difference was statistically significant. The next highest mean CFL is recorded with glass ionomer cement, followed by zinc phosphate cement. These findings are similar to the conclusions drawn by Wolfart et al.\textsuperscript{30} and Mansour et al.\textsuperscript{31} However, this finding contrasts with clinical experience in traditional fixed prosthodontics, as prepared tooth zinc polycarboxylate cement had less or equal retention compared to zinc phosphate cement.\textsuperscript{32}

This is most likely explained by the adhesive properties of zinc polycarboxylate cement. It has been shown that during setting, this type of cement can adhere to tooth structure by chelation of calcium ions\textsuperscript{33} and to metal substrates by chelation of metallic ions.\textsuperscript{34–36} Jendresen and Trowbridge showed that tensile bond strength of polycarboxylate cement for metal–metal adhesion (1300 p.s.i.) was higher than that for metal-tooth adhesion (800 p.s.i.).\textsuperscript{37}

Zinc phosphate cement provides casting retention by micromechanical interlocking into the casting and the abutment surface irregularities. When using smooth titanium implant abutments, the greater compressive strength of zinc phosphate cement compared to polycarboxylate probably does not play a major role in providing retention.\textsuperscript{38}

Glass ionomer cements adhere to dentin and metal in the same manner as polycarboxylate cements;\textsuperscript{39} however, setting reaction may last for 24 hours or more. Early water contact may result in weakening of the cementing agent by dissolution of matrix forming cations and anions in the surrounding areas.\textsuperscript{40} This explains the finding that glass ionomer cement has not offered higher retention values than polycarboxylate cement.

The lowest retentive value in this study was achieved by Premier implant cement. Nevertheless, weakness of the retentive strength could serve other purposes; for example, the lower strength of the provisional cements would facilitate easy retrieval of the prosthesis whenever needed, along with cleaning of the extra cement adhering to it, without damaging the abutment surface.

The location at which cement failure occurs may be another important consideration in the selection of cement when retrievability is desired. All the cements tested in this study demonstrated adhesive failure occurring at the cement–abutment surface (residual cement was generally present inside the coping). The rough sandblasted coping intaglio surface provided greater micromechanical retention than the smooth machined titanium abutment surface; hence, the cement adhered to the coping.

Careful consideration of the choice of cement should therefore include reference to the abutment and crown specifications, opposing surface characteristics, desired retention, and individual properties of the preferred cement. No single retrievable cement can suffice in all clinical situations. Research in future is to be mindful of the fact that most cements currently used in implant dentistry were initially intended for use with natural teeth. The development of cements providing different levels of retention, designed specifically for implant dentistry, may be warranted. Alternatively, dental cements may continue to be selected on a case-by-case basis, according to individual cement advantages and the anticipated requirement for crown retrievability.

**CONCLUSION**

Within the limitations of this study, it is concluded that:

1. The definitive cements produce cement failure load greater than provisional cement and specifically designed implant cement.
2. Zinc polycarboxylate cement has the highest mean cement failure load of all the cements used in this study. The next highest mean cement failure load was recorded with glass ionomer cement, followed by zinc phosphate cement.
3. A lowest retentive value in this study was achieved by specifically designed implant cement (Premier implant cement). Nevertheless, weakness of the retentive strength could favor easy retrievability of the prosthesis.
4. The results do not suggest that one cement type is better than another, but they do provide a ranking order of the cements in their ability to retain the prosthesis and facilitate its easy retrieval.

**REFERENCES**

Luting Agents Used with Implant-Supported Prosthesis


