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RESEARCH AND EDUCATION

Influence of space size of abutment screw access channel on the amount of extruded excess cement and marginal accuracy of cement-retained single implant restorations

Mohammad D. Al Amri, MS,[a] Sulieman S. Al-Johany, MSD,[b] Mohammed N. Al-Qarni, BDS,[c] Ahmed S. Al-Bakri, BDS,[d] Nassr S. Al-Maflehi, MSc,[e] and Haythem S. Abualsaud, MS[f]

ABSTRACT

Statement of problem. The detrimental effect of extruded excess cement on peri-implant tissue has been well documented. Although several techniques have been proposed to reduce this effect by decreasing the amount of extruded cement, how the space size of the abutment screw access channel (SAC) affects the amount of extruded cement and marginal accuracy is unclear.

Purpose. The purpose of this in vitro study was to evaluate the effect of the size of the unfilled space of the abutment SAC on the amount of extruded excess cement and the marginal accuracy of zirconia copings.

Material and methods. Twelve implant replicas and corresponding standard abutments were attached and embedded in acrylic resin blocks. Computer-aided design and computer-aided manufacturing (CAD-CAM) zirconia copings with a uniform 30-μm cement space were fabricated by 1 dental technician using the standard method. The copings were temporarily cemented 3 times at different sizes of the left space of the SAC as follows: the nonspaced group (NS), in which the entire SAC was completely filled, the 1-mm-spaced group (1MMS), and the 2-mm-spaced group (2MMS). Abutments and crowns were ultrasonically cleaned, steam cleaned, and air-dried. The excess cement was collected and weighed. To measure the marginal accuracy, 20 measurements were made every 18 degrees along the coping margin at ×300 magnification and compared with the pre-cementation readings. One-way ANOVA was calculated to determine whether the amount of extruded excess cement differed among the 3 groups, and the Tukey test was applied for multiple comparisons (α=.05).

Results. The mean weights (mg) of extruded excess cement were NS (33.53 ±1.5), 1MMS (22.97 ±5.4), and 2MMS (15.17 ±5.9). Multiple comparisons showed significant differences in the amount of extruded excess cement among the 3 test groups (P<.001). The mean marginal discrepancy (μm) of the pre-cemented group (29.5 ±8.2) was significantly different (P<.01) from that of the NS (72.3 ±13.7), the 1MMS (70.1 ±19), and the 2MMS group (70.1 ±18.8). No significant differences were found in marginal accuracy among the 3 test groups (P=.942).

Conclusions. Within the limitations of this in vitro study, leaving a 2-mm space in the SAC reduced the amount of extruded excess cement by 55% in comparison with the nonspaced abutments. However, no effect was found on the marginal accuracy of zirconia copings. (J Prosthet Dent 2018;119:263-269)

The high success rate of endosseous dental implants makes implant-supported prostheses (ISPs) one of the most predictable options for the replacement of missing single and multiple teeth.[1,2] The ISP can be screw- or cement-retained, but selection of the retention mode of ISPs has been a subject of controversy.[3-8] Each method has been shown to have advantages and disadvantages.[6,9] The cement-retained ISP was introduced to overcome screw loosening and esthetic concerns associated with screw-retained restorations.[10] However, one of

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[a]Professor and Consultant, Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.
[b]Associate Professor and Consultant, Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.
[c]Demonstrator, Department of Prosthetic Dental Sciences, College of Dentistry, Al-Jouf University, Al-Jouf, Saudi Arabia.
[d]Demonstrator, Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.
[e]Lecturer, Department of Periodontics and Community Dentistry, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.
[f]Senior dental laboratory specialist, Dental University Hospital, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.

Clinical Implications

Partially filling the abutment screw access channel may help reduce the extrusion of excess cement into the peri-implant tissue. However, no effect was found on the marginal accuracy of zirconia copings.

the major complications associated with cement-retained ISP is the extrusion of excess cement in the peri-implant sulcus, especially with deep subgingival margins, where ensuring all residual excess cement has been removed is difficult.[8,11-13] Local inflammation, bleeding on probing, and suppuration have been associated with residual excess cement around cemented implant restorations.[14,15] Therefore, remaining cement increases the risk of compromising the peri-implant tissue.[16,17]

A variety of definitive and interim types of cement can be used to cement ISPs.[18] Interim cementation has been recommended to facilitate the retrievability of the restoration if complications arise.[19-21] Zinc oxide eugenol (ZOE) is one of the most commonly used cements for this purpose because of its bactericidal effects, ease of manipulation, and radiopacity.[22,23] However, insufficient retention and frequent de-cementation of the restoration are common when interim cement is used.[24,25] The tensile strength of the cement is also influenced by axial wall tapering, surface roughness and height, width, and material of the abutment.[26-30]

The marginal accuracy of dental restorations is an essential requirement for long-term success.[31-33] Acceptable marginal discrepancy for a restoration has been suggested to range from 50 to 120 μm.[34,35] Recently, the Cercon Smart Ceramics system (Degudent GmbH) has been developed with an acceptable marginal fit for clinical application.[31,36,37] Poor marginal accuracy of cemented ISPs may cause peri-implant inflammation and disintegration of the cement, which would eventually lead to failure of the restoration.[38-42]

Various techniques have been proposed to reduce the residual cement around the margins of cemented ISPs, such as using a crown venting hole[43-46]; modifying the implant abutment[11]; reducing the amount of cement used[47,48]; using a rubber dam[49] or polytetrafluoroethylene tape[50] as barriers for excluding excess cement; modifying the internal configuration of the screw access channel (SAC) by using an insert[51]; and using a custom-made duplicate or practice abutment.[52-54] Other techniques include avoiding deep subgingival restorative margins[9,17] and standard abutments when possible.[11] The effect of abutment internal spacing (leaving some space in the SAC) on the retention and resistance to dislodgement of cement-retained ISPs has been studied.[30,55-57] Other factors that would affect the rate at which the excess cement is forced out of the abutment-crown margin have also been documented.[45,58] However, the authors are unaware of studies of the relationship between the abutment internal spacing and amount of extruded cement and the marginal accuracy of zirconia crowns. It has been hypothesized that increasing the size of unfilled SACs creates a cement reservoir within the abutment. This would modify the cement flow pattern and permit cement to escape into the SAC,[30,45,51,55,59,60] leading to less extruded cement and better marginal adaptation of the restoration.

Therefore, the purpose of this in vitro study was to evaluate the effect of the size of the unfilled space of the SAC on the amount of extruded excess cement and the marginal accuracy of zirconia copings.

MATERIAL AND METHODS

This study used 12 dental implant replicas (Astra Tech Implant System; Dentsply Sirona) embedded in acrylic resin blocks (Vertex Orthoplast; Vertex Dental). Twelve corresponding standard titanium abutments (Tidesign; Astra Tech Implant System; Dentsply Sirona), 4.5 mm wide and 7 mm long, were used without any modifications. The abutments were attached to the implant replicas and tightened to 25 Ncm, using a torque wrench (Torque Wrench EV; Astra Tech Dental Implant; Dentsply Sirona). Twelve computer-aided design and computer-aided manufacturing (CAD-CAM) zirconia copings (Cercon Base; Degudent GmbH) with a uniform 30-μm cement space were fabricated by one dental technician (H.A.) using a standard method.[54] The acrylic resin blocks and zirconia copings were distributed into numbered small envelopes. Matching was randomly performed by picking numbers from a hat. The abutments and copings were identically numbered to avoid interchange afterwards. The SAC was filled with putty impression material (Genie Putty; Sultan Healthcare) and covered with a thin layer of light-polymerized composite resin (Filtek P60; 3M ESPE) to control the space size. A calibrated bone condenser (Bone Graft 3.8SP; Power Dental USA) was used to confirm the size of empty space as follows: nonspaced group (NS) with the entire SAC completely filled; 1-mm-spaced (IMMS) group with a SAC filled, except for the occlusal 1 mm; and 2-mm-spaced (2MMS) group with a SAC filled, except for the occlusal 2 mm. Copings were cemented 3 times using the same cement (TempBond; Kerr Corp) and different sizes of the SAC space (Fig. 1). For convenience, the experiment started with the 2MMS group followed by the 1MMS abutments, where an additional 1-mm filling was added to the SAC. The residual cement from the abutment and the intaglio surface of the crowns was removed mechanically, cleaned with an ultrasonic cleaning solution (Temporary Cement

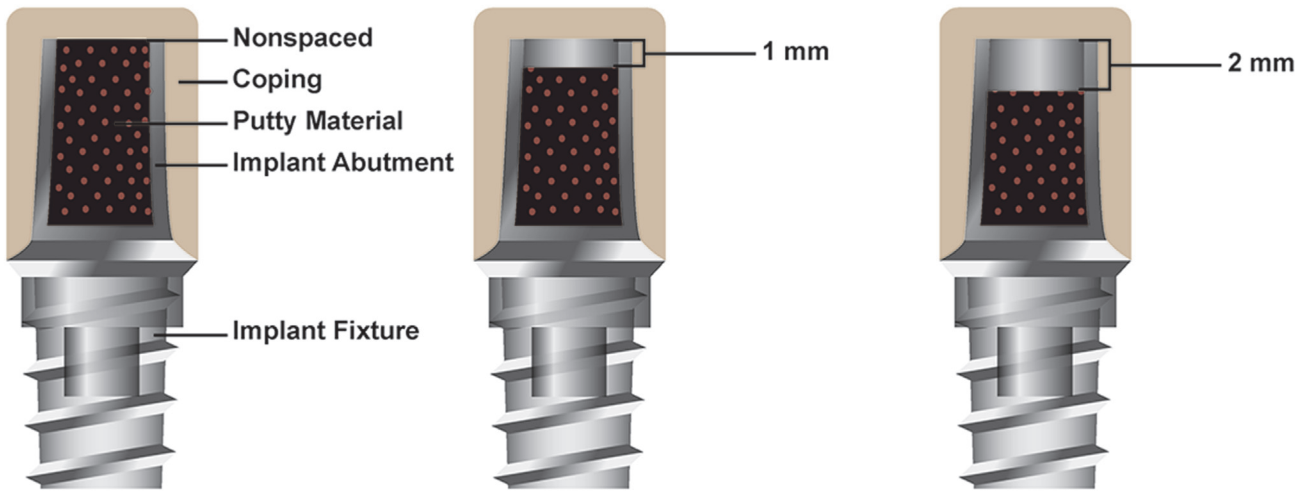

Figure 1. Test groups: (left) nonspaced; (middle) 1-mm spaced; (right) 2-mm spaced.

Remover; Patterson Dental), steam-cleaned (Triton SLA; BEGO), and air-dried.

All cementation was performed according to the manufacturer's instructions by one investigator (A.B.). Vertical aligning lines were added to help orient the coping during cementation (Fig. 2). In order to facilitate the removal of excess cement, a thin layer of separating medium (Vaseline petroleum jelly; Unilever) was applied 2 mm apical all around to the finish margin, using a microbrush (MicroApplicator; Layan Medical Supplies). A digital scale (Mettler CE 150; Mettler-Toledo Intl Inc) and syringes (Automix Syringe; Kerr Corp) were used to standardize the total loaded cement (TLC) amount for all copings. A total of 40 mg of ZOE was loaded in a syringe to fill the occlusal half of the coping.[44,48] Cement-loaded copings were gently seated on the corresponding abutments initially with finger pressure and then by applying a constant load of 50 N for 10 minutes using a compression device (Fig. 2).[61,62] The working and setting times of the cement were controlled to ensure that all copings were cemented with the same cement consistency. After the cement had completely set, the excess cement was collected and weighed on a digital scale (Mettler CE 150; Mettler-Toledo Intl Inc).[53] Weight measurements were repeated 3 times, and the mean scores were recorded for all groups.

Twenty measurements were made every 18 degrees along the margin of the experimental crown as in previous studies.[37,63] Twenty pre-cementation scanning electron microscope (SEM) readings were made for each coping, giving a total of 240 readings. A customized holding device was used to help fix the copings on the abutments and to permit rotation of the specimen (Fig. 3). Likewise, the evaluation of the marginal accuracy of the 3 cemented groups was carried out immediately after removing the excess cement in the same way as for the pre-cemented group, giving a total of 720 readings.

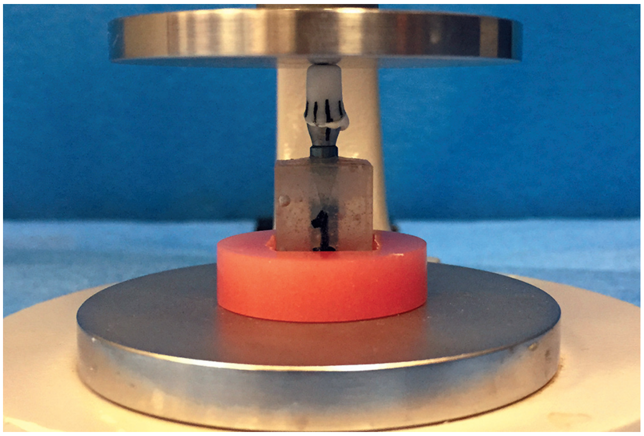

Figure 2. Constant vertical load (50 N) applied through compression device during cementation.

All SEM readings were made by one technician at ×300 magnification.

Statistical analysis was performed using statistical software (PASW Statistics v18; SPSS Inc). One-way analysis of variance (ANOVA) was calculated to determine whether differences could be found in the amount of extruded excess cement among the 3 groups. The Tukey test was applied for multiple comparisons (α=.05).

RESULTS

The amounts of excess cement extruded at the margin in the 3 test groups are presented in Table 1. The NS group showed the highest amount of extruded cement (83.8% of the TLC) among the 3 groups, followed by the 1MMS group (57.43% of TLC). The least amount of extruded cement was produced by the 2MMS group (38% of TLC). Results of the 1-way ANOVA showed a statistically significant difference in the amount of extruded cement among the 3 groups. Likewise, multiple comparisons

Figure 3. Custom holding tool for specimen stabilization during scanning electron microscope measurements.

showed significant differences in the amount of extruded cement among the 3 test groups ($P<.001$).

Marginal accuracy was determined by direct measurements on the SEM images (Fig. 4). Table 2 shows the means and standard deviations of marginal discrepancy before and after cementation. A significant increase in marginal discrepancy was found after cementation of the 3 test groups as compared with the pre-cemented measurements ($P<.01$). However, no significant differences were found among the means of the 3 groups tested ($P=.942$). Multiple comparisons showed no significant differences ($P\geq.390$) in marginal accuracy among the 20 measured points along the coping margin, indicating no effect of variations in the level of the finish line between buccal, lingual, and proximal sides on marginal accuracy.

DISCUSSION

The purpose of this study was to evaluate the effect of different space sizes of the SAC on the amount of extruded cement and on the marginal accuracy of implant zirconia restorations. The tested hypothesis was partially accepted. A significant reduction in the amount of extruded cement was found as the space was increased. However, the hypothesis was rejected when the marginal accuracy was considered, as no significant differences in marginal accuracy were demonstrated in relation to different sizes of SAC space. These results are in agreement with those reported in previous studies.[44,45] The detrimental effect of extruded cement on the peri-implant tissue has been well documented.[11,14,16,45] The amount of cement required to cause disease has yet to be

Table 1. Mean ±standard deviation (SD) extruded excess cement for test groups

Group	Mean (mg)	SD	P
Nonspaced	33.53	1.5	<.001
1-mm spaced	22.97	5.4	<.001
2-mm spaced	15.17	5.9	<.001

determined, but reducing the volume extruded to a minimum would seem reasonable.[45] Therefore, different techniques have been proposed to reduce or eliminate the extruded cement.[11,43-54] A safe approach to avoiding this effect would be by using screw-retained restorations which are more easily retrievable than cemented ISPs; therefore, technical and eventually biological complications could be treated more easily.[9,11-13,17,64] However, cemented ISPs are sometimes unavoidable.

ZOE was used in this investigation to permit easy retrievability and cleanability. The amount of loaded cement was kept constant for all specimens in the 3 groups. Forty milligrams was the amount selected to fill approximately 50% of the coping as previously recommended.[23,47,48] However, clinically, the amount of cement used is at the clinician's discretion with no set standards. Previous surveys of different techniques used for luting ISPs showed diverse cement loading patterns and a lack of consensus regarding the appropriate cement quantity and placement method for cemented ISPs.[65,66]

In the present study, a significant inverse relationship was observed between the volume of cement that may be contained in the SAC and the amount extruded at the abutment-crown margin. This could be due to the presence of internal space for the cement to flow into, which acts as an internal reservoir for cement that may otherwise be extruded through the abutment-crown margin.[60] Therefore, completely occluded abutments had no ability to allow for internal cement flow, forcing the cement outwards.[45] In the present study, the internal volume available for cement (uniform 30-μm cement space plus SAC space) and that of TLC (occlusal half of the coping) in relation to the amount of excess cement extruded at the margin was calculated as described by Wadhwani et al.[45] The available cement space for a nonspaced abutment was approximately 3 mm^3. An additional space of 4.1 mm^3 was added for each 1-mm space left in the SAC. A half-filled coping accommodates approximately 18 mm^3 of cement as the coping tapers occlusally. An extra space of 4.1 mm^3 reduced the amount of extruded cement by 32% in 1MMS abutments and by 55% in 2MMS abutments. These volume calculations confirmed the trend in the extruded cement weights. However, using exactly the correct amount of cement to lute the restoration appears impractical.[51,65] Although larger spaces left in the SAC are expected to be associated with lesser amounts of extruded cement, Wadhwani et al[45] demonstrated a mean reduction of 54% in extruded

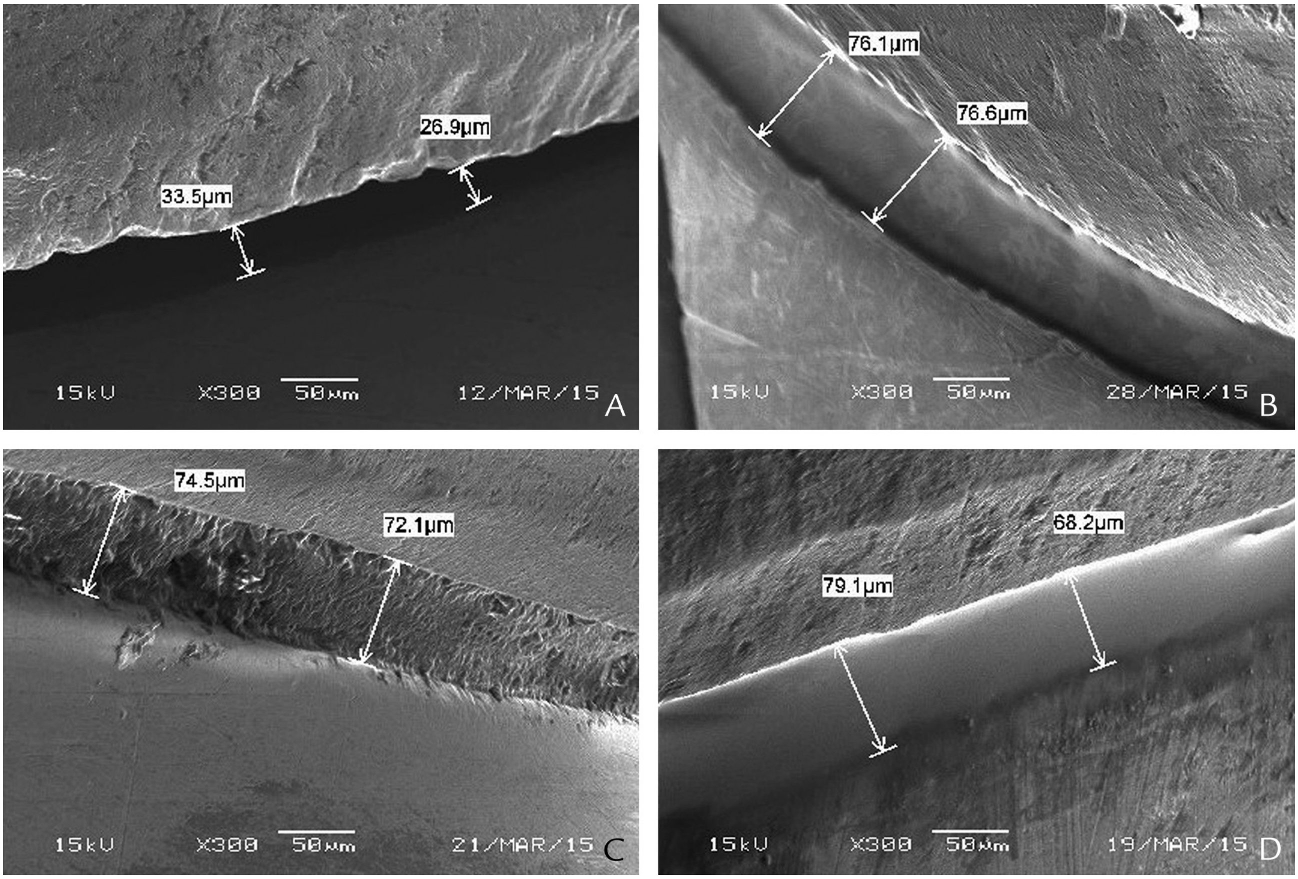

Figure. 4. Scanning electron micrographs (original magnification ×300) of marginal discrepancy measurements of zirconia copings: A, Pre-cemented; B, Nonspaced; C, 1-mm spaced; D, 2-mm spaced.

cement with completely open abutments. This is comparable with that (55%) produced by the 2MMS abutments used in this study despite differences in abutment shape and dimensions, cement space, and the amount of loaded cement between the 2 studies.

The mean pre-cementation marginal accuracy of zirconia copings was 29.5 µm. However, this figure significantly rose to 70.9 µm after cementation, which is within the reported clinically acceptable range of marginal discrepancy.[34,35] This increase in marginal discrepancy after cementation may be related to the modified cement flow pattern and method and site of cement application.[59] Many types of cement are known to be non-Newtonian and are subject to effects such as shear thinning.[59] Such properties can influence their behavior during the seating of a restoration, as the cement flow pattern alters with the shear forces applied during cementation, producing viscosity changes.[59] The cement would be expected to have related viscosity and flow changes according to the speed, site, and volume of the cement applied.[59] The cement flowing down the axial walls would shear much earlier and flow through the margin too quickly to provide a seal.[59] Studies[58,59] have proposed placing cement at the margin of the crown, as a greater cement extrusion occurred and an incomplete margin seal was produced with more occlusally placed cement. This is probably because cement placed closer to the occlusal surface has a greater volume subjected to initial compressive force much earlier as the crown seats.[59]

Table 2. Mean ±SD marginal discrepancy for test groups

Group	Mean (µm)	SD	*P*
Pre-cemented	29.5	8.2	<.01*
Nonspaced	72.3	13.7	.942
1-mm spaced	70.1	19.0	.942
2-mm spaced	70.1	18.8	.942

*Significantly different from cemented groups.

The current study has limitations. The present findings were based on ZOE with the abutment type used and luting space size applied and may not be true for other cements, abutment types, or luting space sizes. Another limitation was the repeated use of copings for the 3 groups. This is pertinent, knowing that zirconia is difficult to clean and that incomplete elimination of cement residues can affect results. However, a meticulous cleaning protocol was followed using mechanical, solution-based, and steam-cleaning. Removing the excess cement at the margin was difficult without it being dissipated. Such a complication may favor using the subtractive method to calculate the excess cement weight over the additive direct method used in this study. This in vitro testing was conducted under dry conditions, but oral humidity and temperature and crevicular fluids may alter cement consistency and flow behavior.[45] Last, the effect of larger space sizes (≥3 mm) left unfilled of the SAC was not evaluated in this study. Therefore, further studies are recommended to investigate the effect of larger space sizes and different cementation techniques on the amount of extruded excess cement, marginal accuracy, and retention.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Leaving a 2-mm space in the SAC reduced the amount of extruded excess cement by 55% in comparison with the nonspaced abutments.
2. No effect was found on the marginal accuracy of zirconia copings.

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Corresponding author:
Dr Mohammad D. Al Amri
Department of Prosthetic Dental Sciences
College of Dentistry
PO Box 60169
King Saud University
West King Abdullah Rd, Riyadh 11545
SAUDI ARABIA
Email: dramri@yahoo.com