An in Vitro Comparison of Antimicrobial Efficacy and Residual Antimicrobial Activity of Root Canal Irrigants Qmix, 3% Sodium Hypochlorite, 2% Chlorhexidine against Enterococcus Faecalis

S Bindu¹, N Shubhashini², I B Geeta³

Abstract: Aim: To evaluate the antimicrobial activity and the residual antimicrobial activity of Qmix, 3% NaOCl and 2% chlorhexidine (CHX) against E. faecalis in human root dentin in vitro. Method: Assessment of antimicrobial activity was done with a dentin disk put into 2 ml Eppendorf tube containing 200μl E.faecalis suspension in BHI broth. The tubes were incubated under anaerobic conditions at 37°C for 3 weeks. The different root canal irrigants of 200 μl each was put in each tube. After 2 min incubation, the dentin blocks were removed and dried with absorbent paper. The biofilm biomass was measured by crystal violet (CV) staining and the absorbance measurement values were obtained by spectrophotometry at 600 nm. Assessment of residual antimicrobial activity of different groups was done by measuring the absorbance values at different intervals of 0 h, 24 h and 48 h by spectrophotometryat 600nm. Results: Qmix showed highest antimicrobial activity followed by 3% NaOCl and 2% CHX against E. faecalis biofilm. The residual antimicrobial activities of the irrigants 2% CHX showed maximum reduction in E.faecalis biofilm at 0 hr. CHX residual antimicrobial activity became significant at 48 h. Qmix showed reduction in E.faecalis biofilm at the end of 48 h NaOCl did not show any residual antimicrobial activity. Conclusion: In conclusion, our study showed that 3% NaOCl, 2% CHX and Qmix could kill E. faecalis in matured biofilm. The antibacterial activity of QMix excelled among the irrigants included in the study and the residual antimicrobial activity of 2% CHX was better than QMix at 24h and 48h respectively. Clinical Significance: Antimicrobial activity and residual antimicrobial activity are important properties of root canal irrigants against persistent microorganisms like E. Faecalis

Keywords: Root canal irrigants; Enterococcus Faecalis; Sodium hypochlorite; Chlorhexidine; QMix root canal irrigant

1. Introduction

It is well established that bacteria and their products play a crucial role in the development of periapical diseases. Sundqvist demonstrated the important role of bacteria play in periapical lesions. (1) Endodontic infections have a polymicrobial nature, with obligate anaerobic bacteria conspicuously dominating the microbiota. E. faecalis has been in focus as a recognized pathogen in endodontics, isolated both in mixed microbiota and in monocultures. (2) It has the ability to colonize the root canal in a biofilm-like style, invade dental tubules, and resist endodontic treatment. The complex anatomy of the root canal system (i.e., isthmuses, accessory canals, and dentinal tubules) enables the survival of bacteria after conventional cleaning. The current techniques in endodontics have been the use of irrigating solutions with strong antibacterial activity along with mechanical preparation of root canal system. The purpose of irrigants used during endodontic treatment is to be antimicrobial, flush out debris, to dissolve organic matter in the canal and provide lubrication to the dentinal walls. (4) Antimicrobial substantivity is the prolonged association between a material and a substrate. The use of irrigants with this property helps ensure residual antimicrobial activity, avoiding the negative impact that bacterial invasion would have on the success of an endodontic procedure. (5) Hence, the present study aims to evaluate the antimicrobial activity and the residual antimicrobial activity of newer irrigant Qmix with 3% sodium hypochlorite and 2% chlorhexidine against E. faecalis.

2. Materials & Methods

A total of 60 extracted non carious single rooted teeth were obtained and stored in distilled water. 60 dentin disks (1cm × 0.5cm × 1 mm [width × length × height]) were prepared by sectioning the coronal one-third of the roots from the cementoenamel junction with a low speed; precision cut diamond saw (Minitom, USA) under continuous water coolant. The dentin disks were steam autoclaved for 30 min under 15 psi pressure at 121 °C to ensure that no bacteria remained. All samples were preserved in 37 °C brain heart infusion for 24 h to test for the presence of bacteria. After confirming complete sterilization, all dentin blocks were stored in sterile saline. Standard strains of E.faecalis preserved at ~80°C was thawed. They were inoculated into freshly prepared BHI and cultivated under anaerobic condition at 37°C for 24h. Then, a bacterial suspension with 1×10^9/ml E.faecalis was obtained by dilution with BHI broth. The dentin blocks with E. faecalis were randomly divided into different groups with 16 samples each. The samples were divided into Group I: Control, Group II: Sodium hypochlorite, Group III: Chlorhexidine, Group IV: QMix

Assessment of antimicrobial activity of different root canal irrigants - One Dentin dentin disk was put into each 2 ml Eppendorf tube and 200μl E.faecalis suspension in BHI broth was added and sealed. The tubes were incubated under anaerobic conditions at 37°C for 3 weeks. The dentin disks were removed and placed in new 2 ml Eppendorf tubes. The different root canal irrigants of 200 μl each was put in each tubes. After 2 min incubation, the dentin blocks were removed and dried with absorbent paper. A Biofilm biomass
measurement by crystal violet (CV) staining was performed. An aliquot of 190 μL of 0.01% CV aqueous solution was added to the tubes containing dentin disks and incubated at room temperature for 30 min. Then, CV solution was removed and wells were washed three times with 200 μL of phosphate buffered saline. During this wash step care was taken not to disturb the biofilm. Then dentine blocks were left to dry for 30 min at 50 °C. Next, 200 μL of 96 –99% ethanol was added to each sample and biofilm was detached by vigorous vortexing. The Absorbance measurement value at 600 nm was obtained by spectrophotometry.

Assessment of residual antimicrobial activity of different root canal irrigants - The remaining dentin disks were incubated in each 2 ml Eppendorf tube and 200μl E. faecalis suspension in BHI broth. The different root canal irrigants of 200 μl was put in each tubes. After 2 min incubation the dentin blocks were removed and dried with absorbent paper. The formed biofilm was washed once with 200 μL of phosphate-buffered saline (PBS). Turbidity was measured at 600nm with plain PBS as reference at different intervals 0 h, 24 h and 48 h by spectrophotometry.

The data obtained was analysed using Statistical Package for Social Sciences (SPSS) for Windows, Version 22.0. Descriptive analysis expression of Optical density values using Mean & SD for each study groups. One-way ANOVA test followed by Post hoc Tukey's Test was used to compare the mean OD values at 600nm by crystal violet method and Residual Antimicrobial activity after treatment at different time intervals between the study groups. The level of significance [P-Value] was set at P<0.05.

3. Results

The mean values were statistically analyzed using One-way ANOVA Test and Multiple comparison of mean differences at 600nm using Tukey's Post hoc Analysis in Tables 1 and 2. It was statistically significant (p<0.001) indicating all irrigants eradicated E. faecalis biofilm.

Table 3-8 show Multiple comparisons of mean differences done for groups at various time intervals of 0 hours, 24 hours and 48 hours respectively using Tukey's Post hoc Analysis. Group II: Sodium hypochlorite showed the maximum reduction followed by Group IV: Qmix at 0 hours and was statistically significant (P<0.001) among all the groups. Group III: Chlorhexidine showed statistically significant reduction between various time intervals of 0 hours, 24 hours and 48 hours respectively demonstrating its residual antibacterial activity. This indicates the irrigant Group IV: Qmix has good antibacterial activity against E. faecalis along with substantivity. However the substantivity of Group III: Chlorhexidine was better among all the groups.

Table 1: Comparison of mean OD values at 600nm by crystal violet method after treatment between study groups using One-way ANOVA Test

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>16</td>
<td>1.3456</td>
<td>0.1114</td>
<td>1.209</td>
<td>1.563</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group II</td>
<td>16</td>
<td>0.1151</td>
<td>0.0161</td>
<td>0.081</td>
<td>0.145</td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>16</td>
<td>0.1099</td>
<td>0.0115</td>
<td>0.089</td>
<td>0.138</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>16</td>
<td>0.0213</td>
<td>0.0127</td>
<td>0.002</td>
<td>0.050</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 2: Multiple comparison of mean differences at 600nm by crystal violet method after treatment using Tukey's Post hoc Analysis

<table>
<thead>
<tr>
<th>(I) Groups</th>
<th>(J) Groups</th>
<th>Mean Diff. (I-J)</th>
<th>95% CI of the Diff.</th>
<th>Lower</th>
<th>Upper</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Group II</td>
<td>1.2305</td>
<td>1.1791</td>
<td>1.2819</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>Group III</td>
<td>1.2358</td>
<td>1.1844</td>
<td>1.2871</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>Group IV</td>
<td>1.3243</td>
<td>1.2729</td>
<td>1.3757</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Comparison of mean OD values at 600nm by residual antibacterial activity test at 0 hr between study groups using One-way ANOVA Test

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>16</td>
<td>0.0906</td>
<td>0.0112</td>
<td>0.078</td>
<td>0.112</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group II</td>
<td>16</td>
<td>0.0149</td>
<td>0.0069</td>
<td>0.003</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>16</td>
<td>0.0239</td>
<td>0.0047</td>
<td>0.003</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>16</td>
<td>0.0157</td>
<td>0.0089</td>
<td>0.003</td>
<td>0.036</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 4: Comparison of mean OD values at 600nm by residual antibacterial activity test at 24 hr between study groups using One-way ANOVA Test

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>16</td>
<td>0.1044</td>
<td>0.0158</td>
<td>0.088</td>
<td>0.134</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group II</td>
<td>16</td>
<td>0.0150</td>
<td>0.0052</td>
<td>0.004</td>
<td>0.023</td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>16</td>
<td>0.0213</td>
<td>0.0050</td>
<td>0.013</td>
<td>0.031</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>16</td>
<td>0.0158</td>
<td>0.0069</td>
<td>0.003</td>
<td>0.026</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 5: Comparison of mean OD values at 600nm by residual antibacterial activity test at 48 hr between study groups using One-way ANOVA Test

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>16</td>
<td>0.1181</td>
<td>0.0126</td>
<td>0.098</td>
<td>0.136</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group II</td>
<td>16</td>
<td>0.0145</td>
<td>0.0049</td>
<td>0.007</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>16</td>
<td>0.0158</td>
<td>0.0054</td>
<td>0.012</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>16</td>
<td>0.0158</td>
<td>0.0043</td>
<td>0.010</td>
<td>0.023</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 6: Multiple comparison of mean differences at 600nm by residual antibacterial activity at 0 hr after treatment using Tukey's Post hoc Analysis

<table>
<thead>
<tr>
<th>(I) Groups</th>
<th>(J) Groups</th>
<th>Mean Diff. (I-J)</th>
<th>95% CI of the Diff.</th>
<th>Lower</th>
<th>Upper</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Group II</td>
<td>0.0364</td>
<td>0.0264</td>
<td>0.046</td>
<td>0.056</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group III</td>
<td>Group III</td>
<td>0.0234</td>
<td>0.0124</td>
<td>0.033</td>
<td>0.043</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Group IV</td>
<td>Group IV</td>
<td>0.0124</td>
<td>0.0024</td>
<td>0.022</td>
<td>0.032</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*Statistically significant
Table 7: Multiple comparison of mean differences at 600nm by residual antibacterial activity at 24 hr after treatment using Tukey's Post hoc Analysis

<table>
<thead>
<tr>
<th>(I) Groups</th>
<th>(J) Groups</th>
<th>Mean Diff. (I-J)</th>
<th>95% CI of the Diff.</th>
<th>Lower</th>
<th>Upper</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Group II</td>
<td>0.0894</td>
<td>0.0806 – 0.0981</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>Group III</td>
<td>0.0831</td>
<td>0.0743 – 0.0918</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>Group IV</td>
<td>0.0886</td>
<td>0.0798 – 0.0973</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td>Group III</td>
<td>-0.0063</td>
<td>-0.0151 – 0.0025</td>
<td>0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td>Group IV</td>
<td>-0.0008</td>
<td>-0.0096 – 0.0080</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>Group IV</td>
<td>0.0055</td>
<td>0.0033 – 0.0143</td>
<td>0.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 8: Multiple comparison of mean differences at 600nm by residual antibacterial activity at 48 hr after treatment using Tukey's Post hoc Analysis

<table>
<thead>
<tr>
<th>(I) Groups</th>
<th>(J) Groups</th>
<th>Mean Diff. (I-J)</th>
<th>95% CI of the Diff.</th>
<th>Lower</th>
<th>Upper</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Group II</td>
<td>0.0757</td>
<td>0.0668 – 0.0846</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>Group III</td>
<td>0.0771</td>
<td>0.0682 – 0.0860</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>Group IV</td>
<td>0.0749</td>
<td>0.0660 – 0.0838</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td>Group IV</td>
<td>-0.0008</td>
<td>-0.0097 – 0.0082</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>Group IV</td>
<td>-0.0022</td>
<td>-0.0111 – 0.0067</td>
<td>0.96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Graph 1: Mean OD values at 600nm by crystal violet method after treatment between study groups

Graph 2: Mean OD values at 600nm by residual antibacterial activity method at different time intervals between various study groups

4. Discussion

The primary goal of endodontic treatment is to optimize root canal disinfection and to prevent its re-infection. It has been shown that bacteria persisting within the root canal system are the major cause of endodontic treatment failures. (2, 4) E. faecalis has been frequently found in persistent intraradicular infections after failed endodontic treatments. (6) The ability of E. faecalis to penetrate dentinal tubules enables it to escape the action of endodontic treatments and irrigants used during chemomechanical preparation. (7) It is resistant to mechanical instrumentation and intracanal antimicrobial agents and has the ability to adapt to the harsh environmental condition. (8) The ideal properties of root canal irrigants described by Zehnder are broad antimicrobial spectrum, high efficacy against anaerobic and facultative microorganisms organized in biofilms, dissolve necrotic pulp tissue remnants, inactivate endotoxin, prevent the formation of a smear layer during instrumentation or to dissolve the latter once it has formed. (9) Surface tension is considered as one of the most important factors in determining the wettability of a solution. Wettability is the property of a fluid to spread over or adhere to a solid surface. This property is required for the chemical solution to penetrate the main and lateral canals, as well as the dentinal tubules and it depends on the surface tension. (10) Several studies have generally concurred that sodium hypochlorite has a broad-spectrum antimicrobial activity. Despite its excellent tissue-dissolving and antimicrobial abilities, NaOCl possesses some drawbacks. One of its major drawbacks of NaOCl is its toxicity. Another major drawback is its high surface tension, which limits it penetration into canal irregularities and the depth of dentinal tubules. (11) Any new concepts and techniques to be used in the clinic should ideally be assessed against their respective gold standards. Hence, our study compared the antimicrobial activity of newer irrigant Qmix against gold standard sodium hypochlorite. QMix™ 2 in 1 (Dentsply a Dental Specialties, Tulsa, OK, USA), contains a mixture of a bishiguanide antimicrobial agent (2% chlorhexidine), a polyaminocarboxylic acid, calcium chelating agent (17% EDTA); saline; and a surfactant (cretirmed). The rationale of adding a surface active agent in QMiX is because of its ability to lower surface tension of solutions and increase their wettability (12, 13) This novel irrigant has been introduced to both remove smear layer and kill bacteria. This irrigant has a proprietary formulation and method of preparation, and has been shown to remove smear layer and kill resistant bacteria, such as E. faecalis, in one application, Mixing EDTA and CHX is known to produce a white precipitate. (14) In QMiX, this is avoided because of its chemical design. A study by Al Khattani et al demonstrated its biocompatibility and also reported that compared to sodium hypochlorite, QMiX is less aggressive and more acceptable to living tissues. (15) Stojicic et al demonstrated that this irrigant has antibacterial activity comparable to NaOCl and superior activity against Enterococcus faecalis in planktonic form and biofilm compared to 2% CHX. (16) The long-term antimicrobial effects rely on whether or not the particular agent has any properties of substantivity. Chlorhexidine is one antimicrobial agent that features this characteristic of...
substantivity. (17) The microorganisms may penetrate into
the root canal via any defects in the coronal aspect of the
tooth and the temporary restorations. Furthermore, re-
infection of the root canal can occur because of re-growth of
any residual microorganisms that have survived the
dodontic treatment procedures. Hence, the use of
antimicrobial agents that exhibit substantivity, that is, agents
that can have a therapeutic effect for a prolonged period.
(18)

Our study also compared the residual antimicrobial activity of
the irrigants used in the study to assess the property of
substantivity. Group III -2% Chlorhexidine showed
maximum reduction in E. faecalis biofilm at 0 hr. CHX
showed less residual antimicrobial activity at 24 h, while its
residual antimicrobial activity became significant at 48 h.
This is similar to results by Rosenthal et al which evaluated
the substantivity of 2% CHX solution within the root canal
system after 10 min of application and they reported that the
CHX was retained in the root canal dentine effective
amounts for up to 12 weeks. (19)

Qmix showed reduction in E. faecalis biofilm at 0 hr. At 24
h, few residual antimicrobial activities were detected in the
QMix group. However, at 48 h, QMix group remained
unchanged. This may be because the unique combination of
Chlorhexidine and EDTA produces synergistic antibacterial
activity helps reduction of bacteria in a single step. This
result is similar to studies by Zhang et al which observed
QMix had less substantivity compared to CHX. (20)

5. Conclusion

Our study showed that irrigants 3% sodium hypochlorite,
2% chlorhexidine and Qmix could kill E. faecalis in matured
biofilm. The antibacterial activity of QMix was best among
the irrigants included in the study followed by 3% sodium
hypochlorite and 2% chlorhexidine. The residual
antimicrobial activity of 2% chlorhexidine was better than
QMix at 24h and 48h respectively.

References

[1] Sundqvist G. Bacteriological studies of necrotic dental
pulp. Umeå Univ. 1976;
analysis of teeth with failed endodontic
treatment and the outcome of conservative re-treatment.
Oral Surgery, Oral Medicine, Oral Pathology, Oral
Radiology, and Endodontology. 1998 Jan 1; 85 (1): 86-
93.
[3] Love RM. Enterococcus faecalis--a mechanism for its role
in endodontic failure. International endodontic journal.
reduction of the bacterial population in
the root canal after instrumentation and irrigation with
1%, 2.5%, and 5.25% sodium hypochlorite. Journal of
efficacy of chlorhexidine as a root canal irrigant: a
literature review. Journal of oral science. 2014; 56 (2):
99-103.
[6] Rôças IN, Siqueira Jr JF, Santos KR. Association of
Enterococcus faecalis with different forms of
periradicular diseases. Journal of endodontics. 2004 May
1; 30 (5): 315-20.
of intracanal bacteria using nickel-titanium rotary
instrumentation and various medications. Journal of
endodontics. 2000 Dec 1; 26 (12): 751-5.
[8] Zhang C, Du J, Peng Z. Correlation between
Enterococcus faecalis and persistent intraradicular
infection compared with primary intraradicular infection:
a systematic review. Journal of Endodontics. 2015 Aug 1;
2005 May 1; 31 (5): 389-98.
effect and surface tension of some chelating
solutions with added surfactants. Brazilian Dental Journal.
effect of 0.5 percent sodium hypochlorite in endodontic
therapy. Oral Surgery, Oral Medicine, Oral Pathology.
Gutmann JL, Pashley D, Tay FR. The effect of
QMix, an experimental antibacterial root canal irrigant,
on removal of canal wall smear layer and debris. Journal
[13] Veetil R, Shubhasini N. An invitro study to evaluate and
compare surface tension of synthetic irrigants with an
alcohol based herbal irrigant. International journal of
scientific research 2019; (9): 9–11.
[14] Basrani BR, Manek S, sodhi RN, Fillery E, Manzur A.
Interaction between sodium hypochlorite and
chlorhexidine gluconate. Journal of endodontics. 2007
Aldahmash AM, Anil S. Cytotoxicity of QMix™
endodontic irrigating solution on human bone marrow
mesenchymal stem cells. BMC oral health. 2014 Dec 1;
14 (1): 27.
[16] Stojicic S, Shen Y, Qian W, Johnson B, Haapasalo M.
Antibacterial and smear layer removal ability of a novel
irrigant, QMX. International endodontic journal. 2012
Apr; 45 (4): 363-71.
[17] Baca P, Junco P, Arias-Moliz MT, Castillo F, Rodríguez-
Archilla A, Ferrer-Luque CM. Antimicrobial substantivity
over time of chlorhexidine and cetrimide. J Endod.
[18] Mohammadi Z, Abbott PV. Antimicrobial substantivity of
root canal irrigants and medicaments: a review.
substantivity in root canal dentin. Oral Surgery, Oral
Medicine, Oral Pathology, Oral Radiology, and
[20] Zhang R, Chen M, Lu Y, Guo X, Qiao F, Wu L. Antibacterial and residual antimicrobial activities against
Enterococcus faecalis biofilm: A comparison between
EDTA, chlorhexidine, cetrimide, MTAD and QMix. Sci