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Gloves contamination during endodontic treatment is one of the 
sources of nosocomial endodontic Propionibacterium acnes infections

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Microbial load of gloves increased from beginning to end of treatment session; gloves should be changed after gaining access to the pulp space and after taking intra-operative periapical radiograph to prevent nosocomial infections of opportunistic bacteria like *Propionibacterium acnes*.

*Statement of Clinical Relevance (max 40 words)*

Microbial load of gloves increased from beginning to end of treatment session; gloves should be changed after gaining access to the pulp space and after taking intra-operative periapical radiograph to prevent nosocomial infections of opportunistic bacteria like *Propionibacterium acnes*. 
Abstract

Introduction
The opportunist Propionibacterium acnes recovered frequently from failed endodontic treatments might be the result of nosocomial endodontic infections. The study was aimed to determine if gloves worn by dentists could be one of the sources of these nosocomial infections and to investigate the P. acnes phylotypes involved.

Methods
The cultivable microbiota of gloves (n=8) at 4 time-points (T1-immediately after wearing gloves, T2-after access-cavity preparation, T3-after taking a working-length/master-cone radiograph, T4-before sealing the cavity) were identified using 16S rRNA gene sequencing. recA gene sequencing of P. acnes isolates was done. The phylogenetic relationship were determined using MEGA 6 (http://www.megasoftware.net/fixed_bugs.html). Data distributions were compared using Fisher’s exact test; means were compared using Mann-Whitney U test in SPSSPC.

Results
The quantitative viable counts at T4 [(aerobically (2.93±0.57), anaerobically (3.35±0.43)] were greater (P<0.001) than at T1 [(aerobically (0.48±0.73), anaerobically (0.66±0.86)] and T2 [(aerobically (1.80±0.54), anaerobically (2.41±0.71)]. 80 cultivable bacterial taxa (5 phyla) were identified. The most prevalent ones were P. acnes and Staphylococcus epidermidis (100%). recA gene sequencing (n=88) revealed 2 phylogenetic lineages with type I split into type IA and type IB. Type II was prevalent on gloves.

Conclusion
Contamination of the gloves was detected at the final stages of the treatment. P.
acnes and *S. epidermidis* are the prevalent taxa on gloves and are opportunistic endodontic pathogens. Changing gloves frequently, *after gaining access into the pulp space and also after taking the working length/master gutta-percha point radiographs*, is likely to reduce the risk of root canal re-infection.

Keywords: *Propionibacterium acnes*, gloves, nosocomial infection
Introduction

*Propionibacterium acnes* (*P. acnes*) is an anaerobic-aerotolerant Gram-positive bacillus that is a commensal bacteria on human skin (1), oral cavity, large intestine, conjunctiva (2) and external ear canal (1, 3). Numerous studies have reported *P. acnes* as an opportunistic pathogen associated with infections and inflammatory conditions (4-7). The *P. acnes* infections are also linked with surgery including brain abscesses (8), osteomyelitis after lumbar puncture (9), spondylodiscitis following epidural catheterization (10), discitis after surgery (11), post-operative mediastinitis (12), endophthalmitis (13) and endocarditis (14). Recently, *P. acnes* is emerging as a well recognized opportunistic pathogen causing various types of medical implant biofilm infection including intraocular implants (15), breast implants (16), neurosurgical shunts like ventroperitoneal and ventroatrial shunts (17), cardiovascular devices like prosthetic heart valve (18), internal fracture fixation devices, spinal hardware (19) and late prosthetic joint infections (20, 21).

Studies in dentistry have also identified *P. acnes* in parotid, periodontal and dental infections (21, 22). *P. acnes* has been identified in studies on the endodontic microbiota (23, 24) but its importance as a pathogenic has largely been ignored, because of its presence on the skin and the consequent likelihood of sample contamination. Recent studies demonstrated that *P. acnes* recovered from primary and refractory endodontic infections is an opportunistic pathogen rather than a contaminant and might be the result of nosocomial infections occurring at the time of root canal treatment (25, 26).

*P. acnes* has been classified into four distinct evolutionary lineages by sequence
analysis of a non-ribosomal housekeeping gene (recA): type IA, IB, II and III, which display differences in inflammatory properties, production of virulence determinants and association with various conditions (21, 27, 28). Previous studies demonstrated that the type II and III were associated with infections of implanted prosthesis (27, 29) and are predominant phylotypes from refractory endodontic lesions (25); whereas type IA and IB that are usually recovered from skin (25, 30) were isolated from primary endodontic cases with “open” communication with the oral cavity (26).

During endodontic treatment, maintaining sterility as much as possible is crucial. Microorganisms can contaminate the root canal if there is insufficient cross infection control leading to root canal failure (25, 31-33). To reduce contamination from the patient to practitioner and vice versa, universal precautions focused on barrier use have been developed (34). The Decontamination: Health Technical Memorandum 01-05: Decontamination in primary care dental practices 2013 version (https://www.gov.uk/government/publications/decontamination-in-primary-care-dental-practices) promotes the use of gloves, masks, protective eyewear, and gowns. The infection control regimens suggested by the ESE 2006 (35) and endodontic textbooks (36, 37) focus on hand washing technique, wearing of Personal Protective Equipment (PPE) to be changed between patients and use of barrier techniques within the surgery. Clean non-sterile boxed gloves are one of the key factors involved in the cross infection control during the endodontic treatment. Studies have shown that gloves can get contaminated before (38, 39) and also after use in clinical dentistry, thus being potential source for microbial contamination of the operative field (34, 40, 41). Contamination of the gloves by patient’s saliva or skin or by bacteria present in the surgery can cause the inoculation of these bacteria into
the root canal during the treatment (41). So far little information is available regarding microbial contamination of gloves during different stages of endodontic treatment session and their role in causing nosocomial endodontic infections. The objective of this study was 2-fold; first to determine the potential source of nosocomial endodontic *P. acnes* infections by investigating the microbiota of the pair of gloves worn by the dentists at 4 different time points during endodontic treatment session and second to investigate the phylotypes of *P. acnes* if isolated among the microbiota present on the gloves.
Material and Methods

Gloves Sampling

Gloves samples were collected from 8 postgraduate endodontic students performing endodontic treatment on patients in the Endodontic Department of the Dental Institute at Guys' and St Thomas' Hospital, King's College London. The clinical operatory surfaces were disinfected prior to treatment using Clinell universal wipes (GAMA healthcare Ltd., London, UK). The surfaces were separated into clean and dirty zones, and cling film barriers applied to the X-ray equipment including the collimator and exposure button, the operating microscope, the dental unit, and dental chair. Barrier sleeves (Henry Schein, Melville, USA) were placed over the 3 in 1 syringe, and hand pieces. The gloves used in this study were commercially available Sempercare® Nitrile Gloves (Sempermed®, Semperit Industrial Products, Birmingham, UK) packaged in boxes of 100 units. The postgraduate dentists were instructed to wear a single pair of gloves for the entire treatment session of a single patient. The dentist used Cutan® hand wash (deb, U.K.) following the 6 steps hand washing technique recommended by Guy’s and St Thomas’ NHS foundation trust (http://www.guysandstthomas.nhs.uk/patients-and-visitors/infection/washing-your-hands.aspx#na). The soap was lathered and rubbed on palms, backs of hands, between fingers, fingertips, thumbs and wrists and nails for 15 seconds up to 1 minute. Hands were rinsed under clean running water and taps turned off without touching them directly. Hands were dried with clean disposable paper towels. The procedure was to comply with the WHO guidelines on hand hygiene in healthcare 2009 (http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf).

Gloves were worn immediately after drying the hands.

The samples were collected using a sterile cotton swabs rubbed all around gloves
worn on both hands at 4 time points during the treatment session; T1- immediately after wearing the gloves at the beginning of the treatment before touching anything with the gloved hands, T2- after access cavity preparation, T3- after taking a working length/master cone radiograph and T4- before sealing of the cavity prior to rubber dam removal (T4). The swabs were suspended into 1ml PRAS medium (Oxyrase, Mansfield, OH, USA) and immediately transported on ice to the laboratory.

Sterile swabs were also collected as negative control from the unhandled gloves taken immediately out from the glove boxes with the help of sterile tweezers. The swabs were plated on to the Fastidious Anaerobe Agar (FAA) supplemented with 5% [v/v] horse blood (Lab M, UK) and incubated anaerobically (in MACS-MG-1000-anaerobic workstation) for 7 days and aerobically for 3 days at 37°C.

**Microbial analysis of samples**

Each sample (T1-T4) was dispersed by vortexing with glass beads, serially diluted in Fastidious Anaerobe Broth (Lab M, UK) and plated onto non-selective media; duplicate plates of FAA supplemented with 5% [v/v] horse blood (Lab M, UK). The FAA plates were incubated anaerobically for 7 days and aerobically for 3 days at 37°C. After incubation colonies were counted, and predetermined number of colonies (anaerobically n = 20/time point, aerobically n = 20/time point, maximum 160/glove) were randomly selected for Gram-staining and molecular identification. The protocol used for selecting and picking the colonies was consistent with the one described in the previous studies (25, 26).
Identification of isolates

All randomly selected isolates were sub-cultured on FAA plates and grown for 24 h.

Bacterial genomic DNA was extracted by boiling 100 μl of a suspension of the cultured cells prepared in sterile dH₂O for 10 min, followed by cooling on ice for 10 min and centrifuged at 13,000 × g for 2 min (21). The supernatant containing the genomic DNA was stored at −20°C prior to analysis. DNA amplification of a partial fragment of the 16S rRNA gene of the isolates was performed using universal primers; 9F (5′-3′ GAGTTTGATCCTGGCTCA) and 907R (5′-3′ CGTCAATTCTTTGAGTT) (42). The amplification was carried out with the following reaction mixture (final volume, 25 μl): 0.5 μl of 9F forward primers (concentration 10 pmol/μl; MWG, United Kingdom), 0.5 μl of 907R reverse primer (concentration 10 pmol/μl; MWG), 23 μl of Reddymix buffer (Thermo Scientific, United Kingdom) and 1 μl DNA extract. The thermal cycling conditions included initial denaturation at 94°C for 10 min, denaturation at 94°C for 30 s, annealing at 49°C for 30 s and extension at 72°C for 90 s, repeated for 34 cycles and final extension at 72°C for 5 min. The amplified products were run on a 0.5% agarose gel (Sigma, United Kingdom) and visualized under UV transillumination. PCR products were cleaned for the sequence reaction with Microclean (Sigma, United Kingdom) according to the manufacturer instructions.

Amplicon sequencing was performed by using an ABI Prism BigDye Terminator sequencing kit (Applied Biosystems) with 30 cycles of denaturation at 96°C for 10 s, annealing at 50°C for 5 s, and extension at 60°C for 2 min. Sequencing reaction products were run on an ABI 3730xl sequencer (Applied Biosystems). All DNA sequences were analyzed, trimmed, and aligned using BioEdit software (version
7.0.0; http://www.mbio.ncsu.edu/BioEdit/bioedit.html). The partial gene sequences were identified by a BLAST search of the NCBI database (http://www.ncbi.nlm.nih.gov/BLAST/), the Human Oral Microbiome database (http://www.homd.org/), or the Ribosome Database Project database (http://rdp.cme.msu.edu/). Phylogenetic trees were constructed by the neighbor-joining (NJ) method, based on 16S rRNA gene sequence comparisons, using the MEGA (version 6) program (http://www.megasoftware.net/).

Phylotyping of *P. acnes* isolates

Gloves *P. acnes* isolates identified by partial 16S rRNA gene sequencing were typed by partial recA gene sequencing (21). All selected *P. acnes* isolates were subcultured on FAA and grown for 24 h.

The *P. acnes* recA gene was amplified using primer PAR-1 (positions –96 to –75; 5’-AGCTCGGTGGGGTTCTTCATC-3’) and primer PAR-2 (positions +1105 to +1083; 5’-GCTTCCTCATACCACTGGTCATC-3’), which generated a 1,201-bp amplicon (21). The reaction mix (final volume, 25 μl) comprised of 0.5 μl of PAR-1 (concentration 10 pmol/μl; Sigma), 0.5 μl of PAR-2 (concentration 10 pmol/μl; Sigma), 23 μl of Reddymix (Thermo Scientific) and 1 μl DNA extract.

The thermal cycling conditions included initial denaturation at 95°C for 3 min, denaturation at 95°C for 1 min, annealing at 55°C for 30 s, and extension at 72°C for 90 s, repeated for 35 cycles, and a final extension at 72°C for 10 min. Amplified products were run on a 0.5% agarose gel and visualized under UV transillumination.

Sequencing was performed as described above. The *P. acnes* recA sequences were
compared with GenBank sequences AY642055 (type IA), EU687255 (type IB),
AY642061 (type II), and DQ672252 (type III). NJ trees were constructed using the
Jukes-Cantor method with MEGA (version 6) software (www.megasoftware.net/).

Statistical analysis

Single Factor: ANOVA was used to compare the quantitative viable counts between
the time points in SPSSPC (Version 21. IBM, USA). Data distributions were
compared using Fisher’s exact test in the PAST-Paleontological Statistics program
(version 3.06).
Results

Quantitative Viable Counts from gloves at 4 time points (T1-T4)

No organisms were recovered from samples taken from unhandled gloves (negative control). The aerobic and anaerobic quantitative viable counts as log_{10} Colony Forming Units (CFU) increased from the beginning (T1) to the end of the treatment session (T4) (Table 1). Few bacteria were detected at the beginning of the treatment at T1, and the microbial load was significantly less (P < 0.001) than that at T2, T3 and T4. The quantitative viable counts at the end of the session (T4) [(aerobically (2.93 ± 0.57) and anaerobically (3.35 ± 0.43))] were significantly greater (P < 0.001) than at the beginning (T1) [(aerobically (0.48 ± 0.73) and anaerobically (0.66 ± 0.86))] and before taking the radiograph (T2) [(aerobically (1.80 ± 0.54) and anaerobically (2.41 ± 0.71)]. Both aerobic and anaerobic viable counts increased from T2 to T3. At T2-aerobic counts were (1.80± 0.54) and increased to (2.44 ± 0.41)] at T3; Similarly at T2-anaerobic counts were (2.41 ± 0.71) and increased to (2.86± 0.68) at T3. Moreover, the aerobic viable counts after taking the radiograph (T3) were significantly greater (P < 0.05) than those before taking the radiograph (T2) (Table 1).

Cultivable taxa from gloves

In the 8 glove samples using 16S rRNA sequencing 80 cultivable bacterial taxa were detected amongst the 776 isolates recovered (Table 2). The mean number of taxa from the gloves samples was 20.5 ± 4.9.

Microbiota was dominated by the Gram-positive facultative anaerobic organisms,
which accounted for 60 of the 80 identified taxa. Moreover, only 2 Gram-positive obligate anaerobes including \textit{Atopobium parvulum} and \textit{Olsenella uli} were identified; whereas 8 Gram-negative obligate anaerobes including \textit{Alloprevotella tannerae}, 4 species of \textit{Veillonella} (\textit{V. dispar}, \textit{V. parvula}, \textit{V. atypical} and \textit{V. rogosae}), 2 species of \textit{Prevotella} (\textit{P. intermedia} and \textit{P. melaninogenica}) and \textit{Fusobacterium periodonticum} were isolated. Two Gram-negative obligate aerobes (\textit{Delftia acidovorans} and \textit{Kocuria sp. Oral taxon 189 Clone AW006}) were also present in the samples (Table 2).

The most prevalent bacterial taxa isolated were \textit{P. acnes} and \textit{Staphylococcus epidermidis} from all 8 gloves samples (100%) (Table 2, Fig. 1). Other Propionibacteria isolated from gloves included \textit{P. avidum} and \textit{Propionibacterium sp. Oral Taxon193 Strain Met-C3}. The mean proportion of \textit{P. acnes} recovered from the gloves samples was 17.6\% (range, 9.5\% to 37.9\%). Staphylococci including \textit{S. epidermidis}, \textit{S. caprae} and \textit{S. warneri} were isolated from the gloves with \textit{S. epidermidis} being the most prevalent one (Table 2, Fig. 1). The mean proportion of \textit{S. epidermidis} recovered from the gloves samples was 18.2\% (range, 8.3\% to 60.2\%). Furthermore, \textit{S. caprae} was present in 87.50\% cases, \textit{Kocuria sp. Oral taxon 189 Clone AW006} and \textit{Streptococcus mitis/oralis} was recovered from 75\% cases; followed by \textit{Corynebacterium urealyticum} and \textit{S. infantis} recovered from 62.05\%. \textit{Actinomyces naeslundii}, \textit{A. odontolyticus}, \textit{S. warneri}, \textit{S. australis}, \textit{S. gordonii}, \textit{S. mitis bv 2} were present on 50\% of the samples (Fig. 1).

**Phylotyping of \textit{P. acnes} isolates recovered from gloves**
Partial recA sequences were obtained for 88 P. acnes isolates and on the basis of sequence alignment, 2 distinct phylogenetic lineages, type I and type II were identified. Type II was the predominant phylotype (n = 37). The Type I isolates segregated into two distinct groups, into which the sequences from known type IA (n = 27) and type IB (n = 24) sequences clustered (Fig. 1).

Comparison of the number of samples of gloves, primary endodontic infections (26) and refractory endodontic infections (25) yielding the different P. acnes recA phylotypes demonstrated that the number of primary endodontic samples (26) with P. acnes type II (1/8) is significantly different (p < 0.05) from both that of glove samples (6/8) and refractory endodontic samples (25). These were the only significant differences between the distribution of the P. acnes phylotypes among the sample types (Fig. 4).

**Richness of bacterial taxa recovered from gloves**

The bacterial taxa identified from the 8 gloves samples belonged to 5 phyla including *Firmicutes, Actinobacteria, Bacteroidetes, Proteobacteria and Fusobacteria* (Fig. 2). The *Firmicutes* was the phylum with the largest number of bacterial taxa, including a variety of 24 different species of Streptococci, 4 Veillonella species, 3 Gemella species, 3 Staphylococcus species, 2 Granulicatella species, in addition to Bacillus anthracis, Paenibacillus sp. Oral Taxon 786 Strain F0064, Parvimonas micra and Peptostreptococcus stomatis (Fig. 2).

The next biggest phylum was *Actinobacteria* with 10 different Actinomyces species, 3 Propionibacterium species, 3 Corynebacterium species, 2 Rothia species, Kocuria
sp. Oral Taxon 189 Clone AW006, A. parvulum, O. uli, Kytopoccus sedentarius and Microbacterium sp. Oral Taxon 184 Strain A43SC (Fig. 2).

Phylum Proteobacteria comprised of 2 species of Neisseria, Haemophilus parainfluenza, Terrahaemophilus aromaticivotans, D. acidovorans, Moraxella osloensis, Agrobacterium tumefaciens, Rhodobacter capsulatus, Brevundimonas diminuta. Phylum Bacteroidetes comprised of 2 species of Prevotella, Capnocytophaga sp. Oral Taxon 336 Clone X089, Alloprevotella tannerae. Moreover, Fusobacterium periodonticum belonging to phylum Fusobacteria was also identified in the samples (Fig. 2).

Discussion

The main aim of the endodontic treatment is the removal of bacteria and their by-products from the root canal space (43). During endodontic treatments an aseptic clinical protocol is essential since bacterial contamination has been shown to contribute to endodontic failure (32). This study demonstrated that the microbial load of gloves worn increased greatly from the beginning to the end of the session. Since the boxed examination gloves, Sempercare® Nitrile Gloves (Sempermed®, Semperit Industrial Products, Birmingham, United Kingdom) are clean but non-sterile therefore a few bacteria were isolated from these gloves at T1 when they were immediately worn before the initiation of patient treatment. Studies have shown that gloves can be contaminated before starting treatment (38, 39). The bacterial counts at T2 after access cavity preparation were significantly greater than at T1. Luckey et al. (2006) showed 10-fold increase in cultivable counts of the gloves after rubber dam placement when compared to freshly worn gloves suggesting that patient contact
through rubber dam placement contaminated gloves significantly (34). In this study the counts after taking the radiograph (T3) and at the end of the treatment session (T4) were significantly greater than those before taking the radiograph (T2). This emphasizes that the bacterial contamination of these gloves might be from either patient’s saliva or skin; or from the bacteria present in the environment/surgery that can be picked during the treatment procedure. Moreover, various studies on the integrity of surgical and examination gloves have showed that all gloves gradually lose their barrier integrity during use (44, 45). This discourages the prolonged use of the gloves to avoid cross-infection between the dentist and the patient. Therefore, we must improve our cross infection control procedures by introducing the protocol of changing the gloves frequently during the endodontic treatment whenever there is potential contamination like this study demonstrated that is after gaining access into the pulp space and also after taking the working length/master gutta-percha point radiographs.

Eighty cultivable bacterial taxa belonging to five phyla were recovered from the gloves samples included in the study. The prevalent taxa found on these gloves included *P. acnes* and *S. epidermidis* (100%); *S. caprae* (87.50%); *Kocuria sp. Oral taxon 189 Clone AW006* and *S. mitis/oralis* (75%); *C. urealyticum* and *S. infantis* (62.05%); *A. naeslundii, A. odontolyticus, S. warneri, S. australis, S. gordonii, S. mitis bv 2* (50%). Furthermore, 24 different types of Streptococci and 10 types of Actinomyces were identified. Interestingly, while comparing with datasets from previous studies on the endodontic microbiota, majority of bacteria recovered from these gloves were consistent with the microbiota recovered from different types of endodontic infections (24-26). This huge diversity of bacteria on the gloves, which
are either picked from patient contact or from the environment, can be the source of nosocomial endodontic infections. The root canal of teeth presenting with irreversible pulpitis and no pre-operative apical radiolucency are unlikely to harbor high number of bacteria and are associated with a higher endodontic treatments success rate as observed in periapical radiographs (46). However, Patel et al. (2012), using reconstructed Cone Beam Computed Tomography (CBCT) images showed that the endodontic treatment of teeth with no pre-operative radiolucency revealed more failures than expected thus depicting the likelihood of bacterial introduction into the root canal space during the endodontic treatment itself despite the use of rubber dam, sterile instruments and the adherence to a strict aseptic protocol (31, 33).

Among the taxa identified from gloves, P. acnes along with S. epidermidis that is already ranked first in the nosocomial medical implant infections (47, 48), were the predominant ones. Recently, P. acnes is emerging as an opportunistic bacteria related to various types of medical implant biofilm infection delete (15-21, 29, 49, 50). This pathogen is considered to be responsible for the chronic or persistent low-grade implant infections, which typically manifested 3 to 36 months or longer after implantation without positive cultures, in which this pathogen is probably under recognized and underestimated (49). The reason for low grade nature of these P. acnes infections is its low virulence, and also encoding for the genes involved in phase variation (51), an adaptation strategy to evade immune responses and eventual degradation. In P. acnes low-grade infection, the inflammatory biomarkers, such as C-reactive protein (CRP), erythrocyte sedimentation rate (ESR) and white blood count (WBC) values are within the normal range and therefore unreliable diagnostic markers (52). Previous studies on the microbiota of endodontic infections
have identified *P. acnes* and coagulase-negative staphylococci, including *S. epidermidis* among the microflora of endodontic infections (23-25). These opportunistic pathogens, isolated from refractory lesion are likely to be the result of nosocomial infections occurring at the time of the root canal treatment and are associated with failures (25). Interestingly, Gomes et al. (2005) showed that sterile gutta percha (GP) cones manipulated by gloves worn during endodontic treatment resulted in 100% of the cones becoming contaminated, with *S. epidermidis* isolated from 93.3% and *P. acnes* from 33.3%. Based on these findings they suggested GP should be manipulated with sterilized tweezers and sterilized with sodium hypochlorite prior to obturation (41).

The genotypic analysis of the gloves *P. acnes* isolates were undertaken to assign these to various phylotypes, so as to compare it with the previous findings where type IA and IB are mostly associated with skin (25, 30) and II and III primarily recovered from implant infections (21, 29) and refractory endodontic infections (25).

Phylogenetic analysis showed that type II was the prevalent phylotypes found on the gloves. Moreover, no significant difference was demonstrated between the number of samples of gloves and refractory endodontic infections (25) yielding *P. acnes* type II. Therefore this study also revealed a potential source of *P. acnes* type II that can lead to nosocomial refractory endodontic infections.

**Acknowledgments**

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The authors deny any conflicts of interest related to this study.
Table 1 Quantitative viable counts of the gloves at 4 time points during endodontic treatment; T1- immediately after wearing the gloves at the beginning of the treatment, T2- after access cavity preparation, T3- after taking a working length/master cone radiograph and T4- before sealing of the cavity prior to rubber dam removal (T4).

<table>
<thead>
<tr>
<th></th>
<th>T1 Mean ± S E</th>
<th>T2 Mean ± S E</th>
<th>T3 Mean ± S E</th>
<th>T4 Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic</td>
<td>0.48 (0.73)</td>
<td>1.80 (0.54)</td>
<td>2.41 (0.71)</td>
<td>2.93 (0.57)</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>0.66 (0.86)</td>
<td>2.44 (0.41)</td>
<td>2.86 (0.68)</td>
<td>3.35 (0.43)</td>
</tr>
</tbody>
</table>

*Values at T2 significantly greater than values at T1 (P < 0.001).
**Values at T3 significantly greater than values at T2 (P < 0.05).
***Values at T3 significantly greater than values at T1 (P < 0.01).
****Values at T4 significantly greater than values at T3 (P < 0.05).
*****Values at T4 significantly greater than values at T1 and T2 (P < 0.001).
Table 2: Distribution of all 80 cultivable bacterial taxa identified among 776 isolates recovered from gloves.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Presence on Gloves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Gram-positive</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Obligate anaerobes</strong></td>
<td></td>
</tr>
<tr>
<td>Atopobium parvulum</td>
<td>−</td>
</tr>
<tr>
<td>Olsenella uli</td>
<td>−</td>
</tr>
<tr>
<td><strong>Facultative anaerobes</strong></td>
<td></td>
</tr>
<tr>
<td>Actinomyces graevenitzii</td>
<td>−</td>
</tr>
<tr>
<td>Actinomyces naeslundii</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces odontolyticus</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 169 clone AG004</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 170 clone AP064</td>
<td>−</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 171 clone JA063</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 172 clone CT047</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 180 strain C3M24</td>
<td>+</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 180 strain C29KA</td>
<td>−</td>
</tr>
<tr>
<td>Actinomyces sp. Oral Taxon 180 strain Hal-1083</td>
<td>−</td>
</tr>
<tr>
<td>Arsenicococcus sp. Oral Taxon 190 Strain B46KS</td>
<td>−</td>
</tr>
<tr>
<td>Bacillus anthracis</td>
<td>+</td>
</tr>
<tr>
<td>Corynebacterium diphtheriae</td>
<td>−</td>
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**Note:** The table above represents the presence (+) or absence (−) of various bacteria in different samples.
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**Gram-negative**

**Obligate aerobes**

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**Obligate anaerobes**

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**Facultative anaerobes**

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References:


46. Ng YL, Mann V, and Gulabivala K. A prospective study of the factors affecting


Figure legends

**Fig. 1** Prevalence of the 80 microbial taxa identified from 8 gloves samples.

**Fig. 2** Phylogenetic tree showing all 80 bacterial taxa belonging to 5 phyla from 776 isolates identified from the 7 gloves samples. The tree was constructed by the neighbor-joining method based on 16S rRNA gene sequence comparisons. The scale bar represents 0.05 substitutions per nucleotide position. The numbers at the node of the tree indicate bootstrap values for each node out of 500 bootstrap resampling.

**Fig. 3** Phylogenetic tree obtained by partial recA sequencing of 88 endodontic *P. acnes* isolates showing three distinct *P. acnes* phylotypes Type IA, IB and II. Neighbor-joining (NJ) tree was constructed using the Jukes-Cantor method with MEGA (version 6). *P. acnes* recA sequences were compared with GenBank sequences AY642055 (type IA), EU687255 (type IB), AY642061 (type II), and DQ672252 (type III). The scale bar represents 0.05 substitutions per nucleotide position. The numbers at the node of the tree indicate bootstrap values for each node out of 500 bootstrap resampling.

**Fig. 4** Comparison of the number of samples of gloves (n=8), primary endodontic infections (n=8) (26) and refractory endodontic infections (n=17) (25) yielding the different *P. acnes* recA phylotypes. Fisher’s exact test was used for analysis.

***The number of primary endodontic samples (26) with *P. acnes* type II (1/8) is significantly different (p < 0.05) from both that of glove samples (6/8) and refractory endodontic samples (25). These were the only significant differences between the distribution of the *P. acnes* phylotypes among the sample types.
Propionibacterium acnes
Propionibacterium avidum
Propionibacterium sp. Oral Taxon 193 Strain Met-C3
Arsenicococcus sp. Oral taxon 190 Strain B46KS
Kytococcus sedentarius
Actinomyces naeslundii
Actinomyces odontolyticus
Actinomyces odontolyticus
Actinomyces graevenitzii
Actinomyces sp. Oral Taxon 172 clone CT047
Actinomyces sp. Oral Taxon 170 clone AP064
Actinomyces sp. Oral Taxon 171 clone JA063
Actinomyces sp. Oral Taxon 169 clone AG004
Actinomyces sp. Oral Taxon 180 strain C3M24
Actinomyces sp. Oral Taxon 180 strain Hal-1083
Actinomyces sp. Oral Taxon 180 strain C29KA
Microbacterium sp. Oral Taxon Strain C24KA
Corynebacterium mucifaciens
Corynebacterium sp. Oral Taxon 184 Strain A43SC
Corynebacterium diphtheriae
Corynebacterium urealyticum
Kocuria sp. Oral taxon 189 Clone AW006
Rothia dentocariosa
Rothia mucilaginosa
Atopobium parvulum
Olsenella uli
Fusobacterium periodonticum
Alloprevotella tannerae
Capnocytophaga sp. Oral Taxon 336 Clone X089
Brevundimonas diminuta
Veillonella dispar
Veillonella parvula
Veillonella atypica
Veillonella rogosae
Prevotella melaninogenica
Prevotella intermedia
Parvimonas micra
Peptostreptococcus stomatis
Rhodobacter capsulatus
Agrobacterium tumefaciens
Agrobacterium tumefaciens
Moraxella osloensis
Delftia acidovorans
Neisseria flavescens
Neisseria mucosa
Haemophilus parainfluenza
Terrahaemophilus aromaticivotans
Granulicatella elegance
Granulicatella adiacens
Paenibacillus sp. Oral Taxon 786 Strain F0064
Bacillus anthracis
Staphylococcus caprae
Staphylococcus warneri
Staphylococcus epidermidis
Gemella morbillorum
Gemella haemolysans
Gemella sanguinis
Streptococcus anginosus
Streptococcus parasanguinis
Streptococcus sp. Oral Taxon 071 Clone C3ALM006
Streptococcus sp. Oral Taxon 061 Clone DN025
Streptococcus constellatus
Streptococcus sp. Oral taxon 064 Clone C5MLM037
Streptococcus sp. Oral Taxon 058 Clone BM035
Streptococcus sanguinis
Streptococcus infantis
Streptococcus mitis
Streptococcus australis
Streptococcus peroris
Streptococcus cristatus
Streptococcus sp. Oral Taxon 066 Clone FN051
Streptococcus infantis
Streptococcus sp. Oral Taxon 431 Clone C4AKM023
Streptococcus australis
Streptococcus australis
Streptococcus parasanguinis
Streptococcus sp. Oral Taxon 184 Clone T4-E3
Streptococcus sp. Oral Taxon 066 Clone FN051
Streptococcus sp. Oral Taxon 065 Clone FN042
Streptococcus salivarius
Streptococcus gordonii
Streptococcus vestibularis
Streptococcus mitis bv 2
Streptococcus australis
Streptococcus australis
Streptococcus australis
Streptococcus sp. Oral Taxon 071 Clone P4PA-13
Streptococcus sp. Oral Taxon 061 Clone DN025
Streptococcus sp. Oral Taxon 066 Clone FN051
Streptococcus sp. Oral Taxon 061 clone DP009
Streptococcus sp. Oral Taxon 158 Clone BM035
Streptococcus sp. Oral Taxon 066 Clone FN051
Associate editor comments:

1) A major concern is the absence of baseline readings, or negative controls, being samples from unhandled gloves immediately out of the box. The T1 samples were taken after the gloves had been handled. Please provide these baseline data or at the very least justify this omission in the discussion.

Answer: We appreciate the comments of the Associate Editor. This study was carried out to investigate the microbial load of the gloves during endodontic use. At this stage it is difficult to repeat the entire experiment to include the baseline CFU’s. However as suggested by the editor and reviewer, we have conducted an experiment to include the negative control. The negative control samples were taken from eight unhandled gloves with the help of sterile tweezers taken immediately out from different glove boxes placed in different clinical surgeries in the Endodontic Department. While holding the gloves with the sterile tweezers, samples were taken with the sterile swab and plated immediately on to the Fastidious Anaerobe Agar (FAA) supplemented with 5% [v/v] horse blood (Lab M, UK). The FAA plates were incubated anaerobically (in MACS-MG-1000-anaerobic workstation) for 7 days and aerobically for 3 days at 37°C.

No organism was recovered from these plates incubated both aerobically and anaerobically.

This is added in the Methods: (Page 6/line 37) and results: (Page 10/line 7)

2) Details need to be included in the Methods section of the hand washing protocol used by the 8 residents providing the samples.

Answer: We appreciate comments of the Associate Editor and Hand washing protocol is added in the Methods section: (Page 6/line 20)

- What hand washing protocols were used prior to placement of gloves?
  - Product used to wash hands?

Answer: The dentist used Cutan® hand wash (deb, U.K.) (www.debskincare.co.uk) following the 6 steps hand washing technique recommended by Guy’s and St Thomas’ NHS foundation trust (http://www.guysandstthomas.nhs.uk/patients-and-visiters/infection/washing-your-hands.aspx#na). The soap was lathered and rubbed on the palms, the backs of hands, between fingers, fingertips, thumbs and wrists and nails for 15 seconds up to 1 minute. Hands were rinsed under clean running water and taps turned off without touching them directly. Hands were dried with clean disposable paper towels. The procedure was to comply with the WHO guidelines.
on hand hygiene in healthcare 2009
(http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf).

- How long after washing their hands did they place the gloves?

Answer: Gloves were worn immediately after drying the hands.

- Did they touch the surface ultimately sampled prior to placing the gloves on their hands?

Answer: The gloves were first worn and then the surfaces of the gloves were sampled. Therefore, there are chances that gloves surfaces that were sampled were handled by bare hands while putting them on.

- Does "immediately after wearing the gloves" mean sampling before touching anything with the gloved hands?

Answer: Yes, at T1 sampling was done immediately after wearing the gloves before touching anything with the gloved hands. This is added in the methods.

- How were the clinic operatory surfaces that would have been touched treated?

Answer: The clinical operatory surfaces were disinfected prior to treatment using Clinell universal wipes (GAMA healthcare Ltd., London, UK). The surfaces were separated into clean and dirty zones, and cling film barriers applied to the X-ray equipment including the collimator and exposure button, the operating microscope, the dental unit, and dental chair. Barrier sleeves (Henry Schein, Melville, USA) were placed over the 3 in 1 syringe, and hand pieces (added in the Methods section).

- Who handled the X-ray equipment – were these surfaces covered with a barrier?

Answer: The postgraduate dentist carrying out the treatment positioned the phosphor plate covered with a Soredex Opticover™ (SOREDEX, UK) within a Rinn endodontic holder (Dentsply, UK) and the x-ray tube, which was covered with a cling film barrier.

3) Figure 4 - suggest including a descriptor for X axis, such as "phylotypes".

Answer: Figure 4 has been corrected as suggested and X-axis title is added as "P. acnes phylotype".
Reviewer #1: The authors should be applauded for writing this noteworthy manuscript titled, "Gloves contamination during endodontic treatment is one of the sources of nosocomial endodontic Propionibacterium acnes infections".

Introduction:

1) "Recent studies demonstrated that P. acnes recovered from primary and refractory endodontic infections is an opportunistic pathogen rather than a contaminant and might be the result of nosocomial infections occurring at the time of root canal treatment (25-28)." References # 27 and #28 do not pertain and support the statement provided by the authors.

Answer: We appreciate comments of the referee and references # 27 and #28 has been deleted and subsequent cited references have been renumbered.

2) Introduction: "Contamination of the gloves by patient’s saliva or skin or by bacteria present in the surgery can cause the inoculation of these bacteria into the root canal during the treatment." Reference is needed.

Answer: Reference has been added.

3) Figure 1 is not legible

Answer: Old Figure 1 has been replaced with the new high resolution Figure 1.

4) Table 1: Why in T3 the Anaerobic microbial count was statistically not significant? Was it a technical error?

Answer: We appreciate the comment of the referee. Table 1 showed that both aerobic and anaerobic viable counts increased from T2 to T3. At T2- Aerobic counts were (1.80± 0.54) and increased to (2.44 ± 0.41)] at T3; Similarly at T2-Anaerobic counts were (2.41 ± 0.71) and increased to (2.86± (0.68) at T3. Statistically significant increase was found between T2 and T3 aerobically. There is no technical error; the results showed that although there was an increase in the viable counts of both aerobic as well as anaerobic bacteria on gloves, however after taking the radiograph only the aerobic bacteria significantly increased on the gloves. This could be related to the contact of the gloved hands with the external surfaces while taking the radiograph like x-ray equipment, which is more likely to harbour aerobic than anaerobic bacteria, which are more commonly present in the oral cavity.

(Page 10/line 27) This has been added in the explanation of results.

"Both aerobic and anaerobic viable counts increased from T2 to T3. At T2-
aerobic counts were (1.80± 0.54) and increased to (2.44 ± 0.41) at T3; Similarly at T2-anaerobic counts were (2.41 ± 0.71) and increased to (2.86± (0.68) at T3. Moreover, the aerobic viable counts after taking the radiograph (T3) were significantly greater (P < 0.05) than those before taking the radiograph (T2) (Table 1)."

5) Discussion: The first paragraph does not add to the paper. I would suggest deleting it.

Answer: (Page 13/line 20) The previous first paragraph has been modified by deleting few lines and adding it in continuation with the previous 2nd paragraph (now 1st paragraph).

Discussion: "This study demonstrated that the microbial load of gloves worn increased greatly from the beginning to the end of the session." Did the authors actually demonstrate this finding? Mann-Whitney statistical analysis does not do that. At T3 there was no statistically significant difference with regards to the anaerobic microbial count. Microbial count at T4 was not significantly greater than values at T3. Values at T3 were not significantly greater than values at T1. Something happened at T3, so my guess is a technical error? The authors need to offer an explanation for this in the Discussion section.

Answer:
- Thank you for the comments. There was a mistake in and Statistical analysis on (Page 9/line 24) has been corrected:

Single Factor: ANOVA was used to compare the quantitative viable counts between the time points.

- The results of the study in Table 1 clearly showed that both aerobic and anaerobic CFU’s increased significantly from the beginning at T1 to the end of the treatment session at T4 (P < 0.001).

- The increase in the aerobic and anaerobic viable counts with the significance difference only found in the aerobic CFU’s is explained while answering the above question.

- Table 1 has been update with more details of the statistical difference and the results showed that at T4 aerobic quantitative viable counts are also significantly greater than those at T3 (P < 0.05). Moreover Values at T3 are significantly greater than T1 (P < 0.001).

Reviewer #2: The authors are commended for raising the awareness of microbial contamination during endodontic treatment.
The authors aimed to study the presence and phylotypes of *P. acnes* in non-sterile dental gloves (1), and correlate the findings with their previous findings that *P. acnes* isolated from refractory endodontic lesions was from patients' skin and oral environment (2). By showing that *P. acnes* was progressively picked up by dental gloves when handling patients during endodontic treatment, the authors put forth a recommendation that non-sterile dental gloves should be changed at suggested time points, so that introduction of *P. acnes* into root canals could be minimized and healing outcome improved (3).

With regards to (1), the presence of *P. acnes* in non-sterile dental gloves and the increase in microbial load as treatment progressed, the authors have shown convincing results.

With regards to (2), that *P. acnes* was progressively picked up from handling patients alone, this is not convincingly shown as there was no control gloves that went through the process of treatment without handling patients. The authors could not conclude that this emphasized the source of contamination (Page 14 Lines 10-17) unless the study is revised to include a control for the operatory environment and equipment as a potential source of *P. acnes*.

**Answer:** We appreciate the comments of the referee. (page 14 Line 10) has been rewritten including other possible sources of *P. acnes* present on the gloves.

This emphasizes that the bacterial contamination of these gloves might be from either patient's saliva or skin; or from the bacteria present in the environment/surgery that can be picked during the treatment procedure.

While the authors might desire to challenge or provide much-needed evidence for the current accepted practice of cross-infection control that includes changing gloves whenever there is a breach or potential contamination, the authors should not make recommendations for specific time-points for changing non-sterile dental gloves (Page 14 Lines 24-34) without studying the minimum quantitative viable counts that would result in refractory endodontic lesions.

**Answer:** We appreciate the comments of the referee. However, in our opinion it is bit more complicated than just minimum number of viable counts that can result in the refractory endodontic lesions; whether or not the refractory infection will occur or not depends other factors such as:

- Bioburden left in the root canal after chemo-mechanical debridment,
- Host immune response

Therefore, if the conditions inside the root canal are in favor of the growth of the bacteria any quantitative viable count above none can lead to refractory endodontic infection.

The reason for recommending the time points for changing the gloves i.e. gaining access into the pulp space and also after taking the working
length/master gutta-percha point radiographs is because these are the sensitive time points where the canal is more likely to be contaminated and the evidence from this study demonstrates that gloves are contaminated at these time points thus increasing the chances of nosocomial contamination.

The statement has been modified. (Page 14 Lines 24)

Therefore, we must improve our cross infection control procedures by introducing the protocol of changing the gloves frequently during the endodontic treatment whenever there is potential contamination like this study demonstrated that is after gaining access into the pulp space and also after taking the working length/master gutta-percha point radiographs.

The manuscript is generally clearly written. However, some spelling and grammatical errors are present and should be corrected before publication.

Answer: The manuscript has been rechecked for spellings and grammatical errors.