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RESEARCH AND EDUCATION

Development of an antimicrobial, 3D printable denture base material with K18 quaternary ammonium silane-functionalized methyl methacrylate and filler

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ABSTRACT

Statement of problem. Denture base materials are highly susceptible to microbial colonization, which can lead to denture stomatitis. In addition, patients who sleep with their dentures have an increased chance of contracting pneumonia. Commercially available antimicrobial denture base materials to prevent or combat microbial colonization are lacking.

Purpose. The purpose of this in vitro study was to determine the effects of K18 quaternary ammonium methacryloxy silane-functionalized filler (K18-Filler) and methyl methacrylate (K18-MMA) on the polymerization of 3D printed denture base material and its esthetic, mechanical, and antimicrobial properties.

Material and methods. K18-Filler (0%, 10%, 20% w/w) and K18-MMA (0%, 5%, 12.5% w/w) were added to a 3D printable denture base resin (Denture Base Resin, Original Pink; Formlabs Inc) and 3D printed. Specimens were tested by using the Rockwell$_{15T}$ hardness, near infrared FTIR monomer-to-polymer degree of conversion (DoC), transparency parameter (TP), color shift, and 3-point bend and by counting colony forming units against *Streptococcus aureus, Streptococcus sanguinis* and *Candida albicans* tests. Data were analyzed using analysis of variance with the Tukey-Kramer HSD post hoc test.

Results. Control resins had significantly higher Rockwell$_{15T}$ hardness than most of the K18 groups ($P<.05$) but had comparable DoC with all K18 groups except one, showing that all groups were well polymerized. Controls had significantly higher TP than most K18 groups, but most K18 groups had $\Delta E<3.3$, so the color shift was not noticeable. However, the 12.5% K18-MMA with 10% and 20% K18-Filler groups, which were also the groups used to test for antimicrobial activity, had $\Delta E>8$. All K18 groups had comparable or greater moduli than the controls, but the controls had significantly higher ultimate transverse strengths than most K18 groups ($P<.05$). All 12.5% K18-MMA with K18-Filler groups had significant antimicrobial activity against *S. aureus*, *S. sanguinis*, and *C. albicans*.

Conclusions. 12.5% K18-MMA and K18-Filler produced 3D printable denture materials with comparable polymerization properties and significant antimicrobial properties against *S. mutans*, *S. sanguinis*, and *C. albicans*. High K18-MMA and K18-Filler concentrations caused significant color shifts and reductions in ultimate strengths. (J Prosthet Dent 2024;131:1251.e1-e8)

A total of 8.6 million edentulous Americans are predicted by 2050.[1] However, conventional dentures have high patient cost and extensive fabrication time. Three-dimensional (3D) printing eliminates the need for physical impressions and casts, reduces the number of visits, and may also reduce allergic reactions, since patients do not need to interact with the numerous materials used to make conventional dentures.[2–7] However, conventional and 3D printed dentures are susceptible to microbial colonization, especially by *Candida albicans*, which can lead to denture stomatitis, inflammation, redness, and irritation of the oral tissue.[8–10] Worldwide, approximately 65% of complete denture wearers experience denture stomatitis.[10,11] Furthermore, the risk of pneumonia can double for patients who sleep with their dentures because *C. albicans* and bacteria coexist in the same biofilm on denture materials.[12,13] Pneumonia is a serious problem that, coupled with poor prognosis, has a mortality rate of approximately 20% among community-dwelling elders.[14,15]

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Clinical Implications

Complete denture wearers experience denture stomatitis, and patients who sleep with their dentures have an increased chance of contracting pneumonia because denture base materials are highly susceptible to microbial colonization. A definitive antimicrobial denture base material that does not elicit resistance to antibiotics or antifungal agents will be highly beneficial.

Attempts have been made to develop denture base materials with antimicrobial properties.[16–25] However, problems with rapid degradation, biocompatibility, and only short-term or delayed antimicrobial activity have been identified.[16–25] K18 quaternary ammonium methacryloxy silane (QAMS) copolymerized into polymethyl methacrylate (K18-PMMA) has been reported to have biocidal properties against oral bacteria and fungi, including *C. albicans*.[26,27] K18 contains a tetraethyl ortho silicate silane core ($Si(OC_2H_5)_4$) that is covalently bound to a quaternary ammonium (Si-Quat) compound, which can pierce bacterial cell membranes and lyse cells via a long, lipophilic $C_{18}H_{37}$ alkyl chain.[27–29] The acrylate functionality on the silane core allows K18 to copolymerize with acrylic monomers, rendering the material antimicrobial. Also, the silane core allows K18 to functionalize glass filler particles (K18-Filler). Since K18 does not leach out, it is expected to be permanently antimicrobial and should be harder for bacteria to acquire resistance to.[26,27] The inorganic silica core, which is naturally stronger than organic polymers, may lead to improved mechanical properties.[30]

Thus, the objective of this work was to develop an antimicrobial, 3D printable denture base material incorporating K18. The research hypothesis tested was that adding K18-MMA and K18-Filler to a 3D printable denture base material would render it antimicrobial without detrimentally affecting polymerization, esthetics, or mechanical properties.

MATERIAL AND METHODS

K18-Filler (0%, 10%, and 20% w/w) and K18-MMA (30% w/w K18 in MMA, 0%, 5% and 12.5% w/w) (FiteBac, Inc) were added to a printable denture base resin (Denture Base, Original Pink; Formlabs Inc). Resins with higher K18-MMA and K18-Filler concentrations could not be printed because of high viscosity and clumping. Twenty-five Ø10×2-mm disks and five 2×2×25-mm rectangular bars for each print angle of 0, 45, and 90 degrees (15 total) were 3D printed in a stereolithography (SLA) printer (Moai Laser Printer; Peopoly) at a laser power of 58 mW, Z motor speed of 8 mm/minute, and PM motor speed of 30 mm/minute. The specimens were removed from the build plate, rinsed with isopropyl alcohol, postpolymerized in glycerin at 75 °C for 30 minutes, and light-polymerized for 40 minutes. The specimens were tested using a $Rockwell_{15T}$ hardness tester, Fourier-transform near infrared (FTIR) spectroscopy, degree of monomer-to-polymer conversion (NIR DoC), transparency parameter (TP), color shift, 3-point bend test, and colony counting against *S. aureus, Streptococcus sanguinis,* and *C. albicans* tests.

The $Rockwell_{15T}$ hardness was measured (Wilson 3JR tester; Wilson, Inc) with a 15 T ballpoint Ø1.57-mm indenter (n=5) as described previously.[31] Three measurements were made per specimen to ensure that the resin had been uniformly polymerized. NIR DoC was determined (Nicolet 6700 FT-IR Spectrometer; Thermo Fisher Scientific) using the C=C acrylate peak at 6165 cm^{-1} as described previously.[31] The DoC was calculated from: $\mathrm{DoC} = \left(1 - \frac{[Abs\ polymerized]}{[Abs\ unpolymerized]}\right) \times 100$, where *Abs* is the peak height of absorption for the polymerized and nonpolymerized specimens.

TP was determined with a colorimeter (CR-400 Chroma Meter; Konica Minolta) on calibrated black and white backgrounds and the color difference equation $\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$, where L^*, a^*, and b^*, are the color notations in the CIELab system, and ΔL, Δa, and Δb are the differences in those values measured on the same specimen above a calibrated white or black background. Color shift from the original denture base material was measured with the same formula as TP, but ΔL, Δa, and Δb were the differences in those values between the experimental specimen and the average control specimen on a calibrated white background.

Mechanical properties (modulus of elasticity and ultimate transverse strengths) of bar specimens were determined with an Instron machine (Instron) in 3-point bend mode at a crosshead speed of 1 mm/minute after immersion in water at 37 °C for 24 hours as described previously.[31]

Antimicrobial properties against *S. mutans* and *S. sanguinis* were determined with a colony counting assay.[32] After culturing the bacteria overnight, bacterial density was adjusted to 0.2 at $OD_{620\,nm}$. A 1:1000 dilution of the inoculum was used as the initial bacterial suspension, and 0.5 mL of that suspension was added to tubes containing Ø6×2-mm resin specimens (n=7). Tubes were incubated in a Coy anaerobic chamber (5% CO_2, 10% H_2, 85% N_2) at 30 °C for 24 hours and then 37 °C for 24 hours under anaerobic conditions. Inoculation cultures were diluted in Trypticase soy broth (TSB) in seven 10-fold ($1:10^{-1}$) serial dilutions to $1:10^{-7}$. Aliquots (20 µL) of each dilution were plated with Trypticase soy agar plates, and colony forming units

were counted to determine the inhibitory effect of the control and K18 denture materials. For *C albicans*, a similar method was used, except the specimens were inoculated at 30 °C for 24 hours and transferred to agar plates at room temperature for counting colonies.

Previous work using a statistical software program (G*Power 3.1; Heinrich Heine University Düsseldorf) has shown that the stated sample sizes for each test had an 85% statistical power. The adequacy of the power of the sample sizes and normality and the homoscedasticity of the data were verified (Statskingdom.com). Thus, analysis of variance (ANOVA) with the Tukey-Kramer HSD post hoc test was used to determine significant differences among groups (α=.05) (https://acetabulum.dk/anova.html).

RESULTS

The Rockwell$_{15T}$ hardnesses and NIR DoC results (Fig. 1) show that the Formlabs control group (82.3 ±4.4 RHN) was significantly harder than all K18 groups (*P*<.05), except the 10% K18-Filler, 5% K18-MMA, and 5% K18-MMA+20% K18-Filler groups (81.2 ±4.9 RHN, 80.7 ±1.5 RHN, and 81.0 ±1.4 RHN, respectively). Other statistically significant differences among groups are noted in the figure legend, but all groups were well polymerized.

Controls (80.0 ±1.0%) had significantly higher DoC than the 10% K18-Filler group (74.0 ±2.9%) (*P*<.05) but comparable DoC with all other K18 groups. The 10% K18-Filler group also had significantly lower DoC than the 5% K18-MMA and 12.5% K18-MMA groups (80.3 ±0.8% and 81.0 ±4.9%, respectively, *P*<.05); however, trends were not identifiable, and no correlations with hardness data were observed because all groups were well polymerized (DoC 74 to 81%).

The TP and color shift from the control (ΔE) results (Fig. 2) show that the controls (TP=25.4 ±1.3) had significantly higher TP than all groups (*P*<.05), except the 10% K18-Filler and 12.5% K18-MMA groups (TP=24.8 ±0.9 and 24.6 ±0.6, respectively). An increase in K18-Filler loading led to decreased TP for groups with 0% and 20% K18-MMA, and groups with 20% K18-Filler had the lowest TPs. The exception was the 5% K18-MMA group, which had low TP (TP=22.9 ±0.8).

The 12.5% K18-MMA with 10% and 20% K18-Filler groups were whiter, had ΔE>3.3 (red dashed line, above

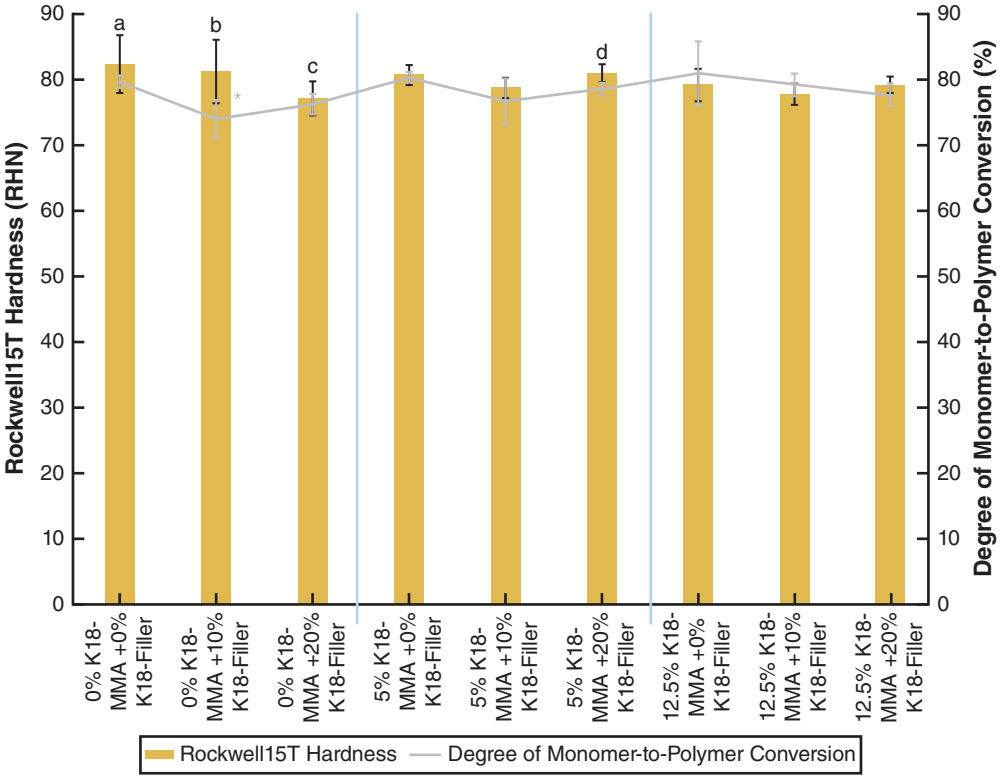

Figure 1. Degree of polymerization of Formlabs control and K18-containing 3D printable denture base materials. Bars=Rockwell$_{15T}$ hardness. Line=Near infrared FTIR degree of monomer-to-polymer conversion (DoC). a, Formlabs control group significantly harder than 20% K18-Filler group, 5% K18-MMA+10% K18-Filler group, and all groups containing 12.5% K18-MMA (*P*<.05). b, 10% K18-Filler group significantly harder than 20% K18-Filler and 12.5% K18-MMA+10% K18-Filler groups (*P*<.05). c, 20% K18-Filler group significantly softer than Formlabs control, 10% K18-Filler, 5% K18-MMA, and 5% K18-MMA+20% K18-Filler groups *P*<.05). d, 5% K18-MMA+20% K18-Filler group significantly harder than 20% K18-Filler and 12.5% K18-MMA+10% K18-Filler groups *P*<.05). * 10% K18-Filler group has significantly lower DoC than Formlabs control, 5% K18-MMA, and 12.5% K18-MMA groups (*P*<.05).

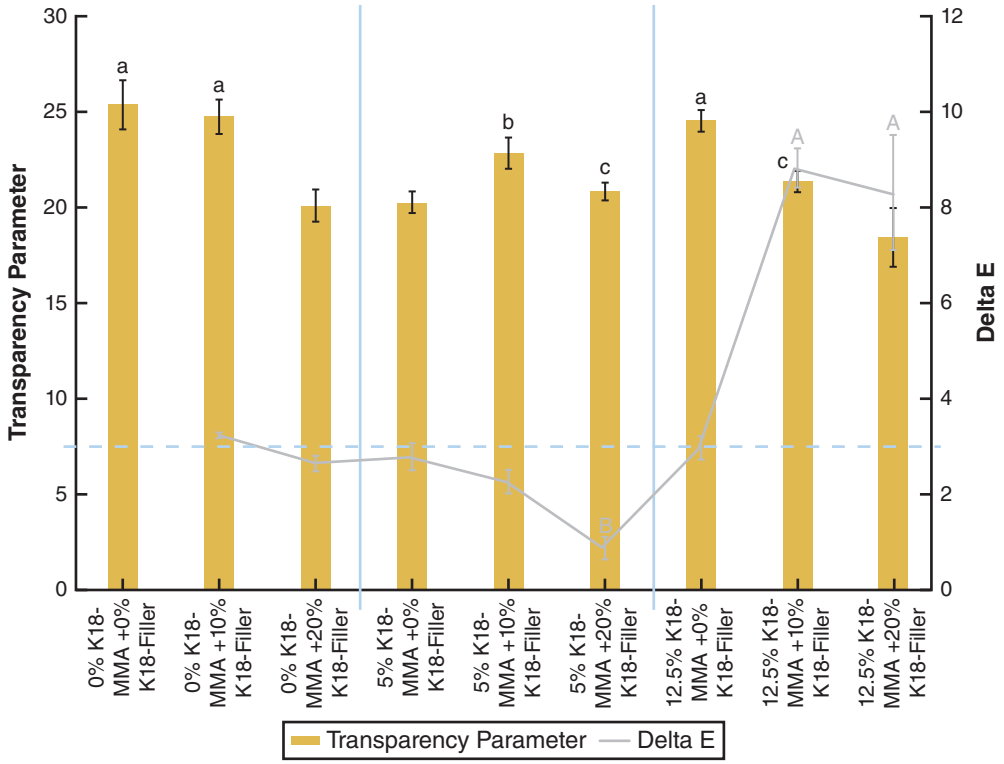

Figure 2. Esthetic properties of Formlabs control and K18-containing 3D printable denture base materials. Bars=Transparency parameter (TP). Line=Color shift (ΔE). a, Formlabs control, 10% K18-Filler and 12.5% K18-MMA groups significantly higher TP than all other groups (P<.05). b, 5% K18-MMA+10% K18-Filler group significantly lower TP than Formlabs control, 10% K18-Filler, and 12.5% K18-MMA groups, but significantly higher TP than all other groups (P<.05). c, 5% K18-MMA+20% K18-Filler and 12.5% K18-MMA+10% K18-Filler groups significantly lower TP than Formlabs control, 10% K18-Filler, 5% K18-MMA+10% K18-Filler and 12.5% K18-MMA groups, but significantly higher TP than 12.5% K18-MMA+20% K18-Filler group (P<.05). A, 12.5% K18-MMA groups with 10% or 20% K18-Filler have significantly higher ΔE than all other groups (P<.05). B, 5% K18-MMA+20% K18-Filler group has significantly lower ΔE than all groups (P<.05).

which color shift is perceivable), and had significantly higher ΔE (ΔE=8.84 ±0.41 and 8.33 ±1.20, respectively) than all groups (P<.05). The 5% K18-MMA+20% K18-Filler group had significantly lower ΔE (ΔE=0.89 ±0.23) than all groups (P<.05). An increase in K18-Filler seemed to be associated with decreased ΔE, but that trend did not hold for the groups with 12.5% K18-MMA, where the ΔE increased. There may have been a synergistic effect with 12.5% K18-MMA and K18-Filler. Regardless, most groups had ΔE<3.3, and the color shift was not clinically significant.[33]

No significant differences were found to be associated with print angle, so the data for each group printed at the different angles were combined. Three-point bend test results (Fig. 3) show that all K18 groups, except the 12.5% K18-MMA group, had comparable or greater moduli than the controls. K18-Filler tended to increase the modulus except for groups with 5% K18-MMA, but K18-MMA had little effect. Controls and 20% K18-Filler groups had significantly higher ultimate transverse strengths (UTSs) (80.0 ±16.2 MPa and 84.2 ±11.0 MPa, respectively) than the 5% K18-MMA+20% K18-Filler group and groups with 12.5% K18-MMA (P<.05). K18-Filler increased UTS when K18-MMA was not present but had no effect with K18-MMA. Other differences are noted in the figure legend.

To ensure antimicrobial properties, only groups containing 12.5% K18-MMA were tested. Antimicrobial test results (Fig. 4) show that both 12.5% K18-MMA and K18-Filler are needed for significant antimicrobial activity against *S. mutans*. The control and 12.5% K18-MMA with no K18-Filler groups had significantly greater *S. mutans* colony forming units (CFU) than all other groups (*S. mutans* CFU reduction of 46% to 64%, P<.05). Controls had significantly greater *S. sanguinis* CFUs than all K18 groups (*S. sanguinis* CFU reduction of 37% to 56%, P<.05). Antimicrobial test results (Fig. 5) show that all K18 groups had significant antimicrobial activity against *C. albicans* (*C. albicans* CFU reduction 70% to 83%, P<.05).

DISCUSSION

Conventional and 3D printed dentures are colonized by microbes that can be associated with denture stomatitis

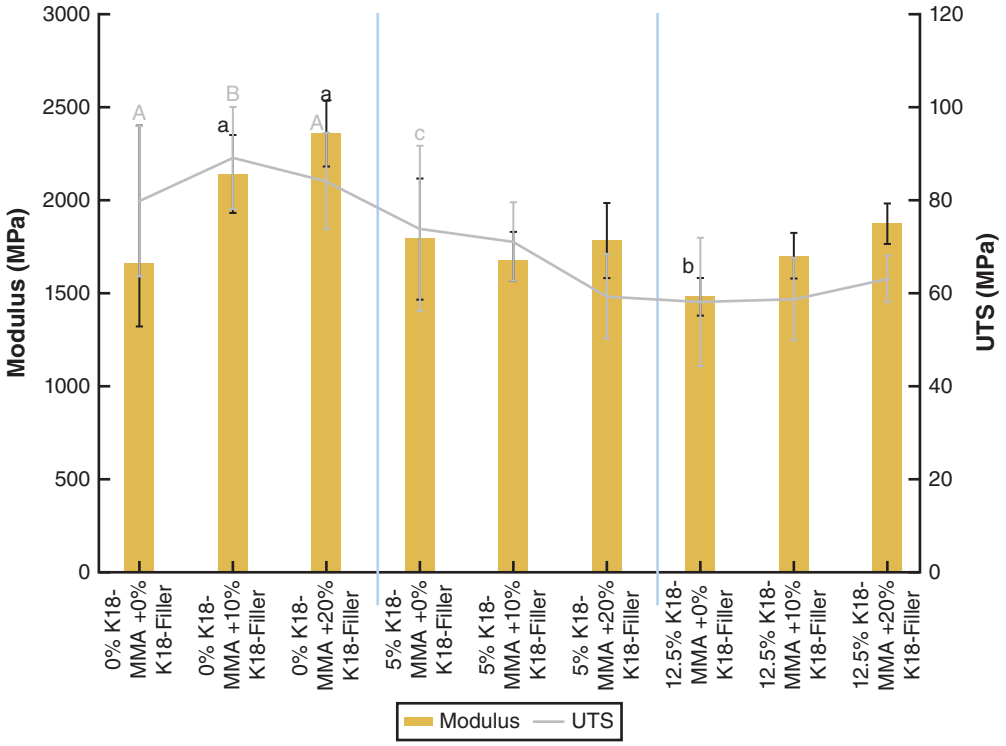

Figure 3. Mechanical properties of Formlabs control and K18-containing 3D printable denture base materials. Bars=Modulus. Line=Ultimate transverse strength (UTS). a, 10% and 20% K18-Filler groups significantly higher moduli than all groups ($P<.05$). b, 12.5% K18-MMA group significantly lower modulus than all groups except 12.5% K18-MMA+10% K18-Filler group ($P<.05$). A, Formlabs control and 20% K18-Filler groups significantly higher UTS than 5% K18-MMA+20% K18-Filler group and all groups containing 12.5% K18-MMA ($P<.05$). B, 10% K18-Filler group significantly higher UTS than all groups containing K18-MMA ($P<.05$). C, 5% K18-MMA group significantly higher UTS than 5% K18-MMA+20% K18-Filler group and 12.5% K18-MMA groups with 0% or 10% K18-Filler ($P<.05$).

and pneumonia.[8–10,12,13] Thus, the effects of K18 QAMS-functionalized methyl methacrylate (K18-MMA) and glass filler (K18-Filler) on the physical and antimicrobial properties of 3D printable denture base material were investigated. The research hypothesis that K18-MMA and K18-Filler would render 3D printable denture base material antimicrobial without detrimentally affecting polymerization or esthetic or mechanical properties was accepted.

In general, K18 denture materials were well printed. The K18-Filler and/or K18-MMA did decrease the $Rockwell_{15T}$ hardness for most formulations, but those values were within 10% of those of controls. The decrease may have been because the high K18-Filler loading decreased TP and affected light polymerization. However, the hardness and TP results did not correlate. Furthermore, the DoC results showed no significant differences between the control and K18 groups. Thus, the narrow standard deviations in the hardness results may have elucidated subtle differences, and the TP reduction was not significant enough to affect resin polymerization.

The current results are important as the use of antimicrobial agents tends to affect resin polymerization.[16] A NextDent 3D printed denture material containing 2.0% w/w silver-loaded mesoporous silica nanoparticles was reported to decrease DoC by approximately 20%, and increased silver nanoparticle (AgNP) concentration was reported to decrease PMMA hardness and only up to 0.15% w/w could be loaded.[17,20] However, a study using QAMS copolymerized with PMMA (QAMS-PMMA), an agent similar to K18-MMA, showed no detrimental effect on polymerization.[27] In the present study, a reduction in polymerization was expected because, as the commercially available denture base initiator system is proprietary, the initiation system was not optimized. Nonetheless, specimens were well polymerized. Thus, any differences in mechanical properties can be attributed to factors other than DoC.

TP, K18-MMA, and K18-Filler did not significantly affect color shift, ($\Delta E<3.3$) except for the 12.5% K18-MMA with 10% or 20% K18-Filler groups ($\Delta E>8$). This finding was consistent with that of a previous study,[18] where denture resins with 0.3% and 0.6% methacryloyloxyundecylpyridinium bromide had $\Delta E<3.3$. However, antimicrobial denture resins with AgNPs had significant color change, turning amber to black with increasing AgNP concentration.[20] Color shift can be amended by adjusting pigment concentrations.

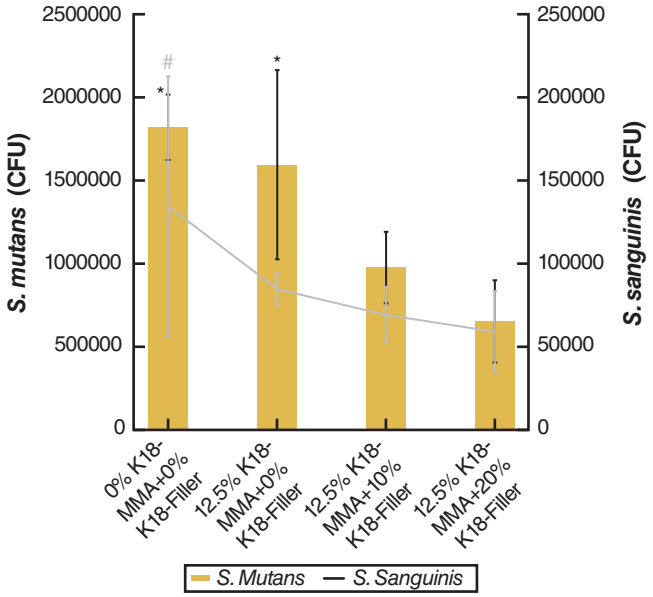

Figure 4. Antimicrobial properties of Formlabs control and K18-containing 3D printable denture base materials against *S. mutans* and *S. sanguinis*. Bar=*S. mutans*. Line=*S. sanguinis*. * Formlabs control and 12.5% K18-MMA with no K18-Filler groups significantly higher *S. mutans* CFUs than 12.5% K18-MMA with 10% or 20% K18-Filler groups ($P<.05$). #: Formlabs control group has significantly higher *S. sanguinis* CFU's than 12.5% K18-MMA with 10% or 20% K18-Filler groups ($P<.05$).

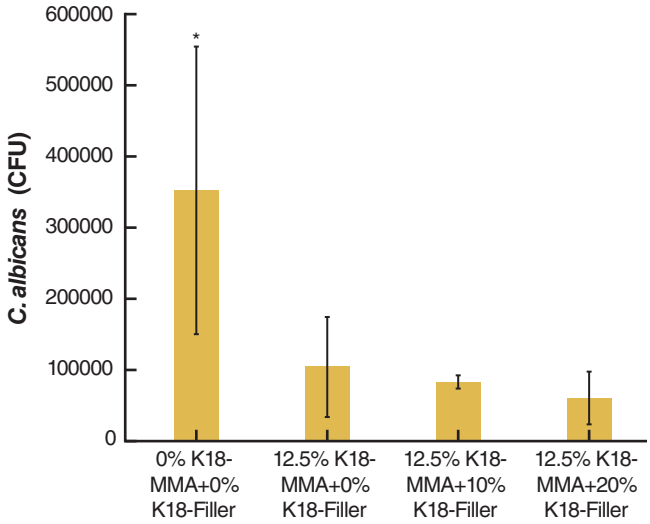

Figure 5. Antimicrobial properties of Formlabs control and K18-containing 3D printable denture base materials against *C. albicans*. * Formlabs control group significantly higher *C. albicans* CFU's than all K18-containing groups ($P<.05$).

Most K18 resins had comparable or greater moduli than the controls. As expected, the K18-Filler tended to increase the modulus because of the composite structure.[34] However, K18-MMA decreased that effect on the modulus. Regardless, only one K18 group had a lower modulus than the controls. This finding was important because MMA only has 1 functional group as compared with the difunctional monomers in the Formlabs resin. Difunctional monomers can form crosslinked materials, which generally have higher moduli.[34]

The K18-Filler increased UTS from approximately 80 to 89 MPa, since glass fillers tend to increase mechanical properties. However, K18-MMA led to decreased UTS. The DoC results showed that all groups had comparable degrees of polymerization, so these results may reflect the difference in the strengths of the K18-MMA and the Formlabs monomers and the decrease in crosslinking that occurred with increased monofunctional MMA concentration.

In a study comparing CAD-CAM denture base materials,[35] the Formlabs denture base material printed with a Formlabs printer had a UTS and modulus of approximately 69 MPa and 4800 MPa, respectively. In another study,[36] the Formlabs denture base resin printed with a Formlabs printer had UTS and modulus values of approximately 123 MPa and 1400 MPa, respectively. Formlabs advertises that their denture base resin has a UTS >65 MPa. Modulus values are not provided.[37] The UTS and modulus values of the Formlabs Control group printed using a Peopoly Moai Laser SLA Printer in this study (approximately 80 MPa and 1700 MPa, respectively) are consistent with those of previous studies.[35–37] Thus, the Peopoly printer does not seem to be a confounding factor.

All K18 groups had moduli >1480 MPa, and most had a UTS >65 MPa. However, the UTS for the group with the highest antimicrobial activity (12.5% K18-MMA+20% K18-Filler) was approximately 63 MPa, which was slightly lower than the values for Formlab but within 5%. The decrease in UTS was consistent with the results in a study of QAMS-PMMA,[27] where 2% QAMS decreased the modulus and UTS. The K18-MMA used in the present study contained 30% w/w K18 in MMA. Thus, the 12.5% w/w K18-MMA group had the equivalent of 3.75% w/w QAMS in the QAMS-PMMA.[27] This, combined with the possibility that the K18-MMA was inherently weaker than the Formlabs difunctional monomers, could be a factor in the decrease in UTS, despite the modulus not decreasing.

Despite results showing that high K18-MMA concentration increased color shift and decreased UTS, the study of QAMS-PMMA[27] showed that the equivalent of 12.5% w/w K18-MMA was required for antimicrobial activity. Thus, only those groups were tested in the present study. Resins with 12.5% w/w K18-MMA and no K18-Filler significantly decreased in antimicrobial activity for *S. Sanguinis* and *C. Albicans* but not for *S. mutans* ($P<.05$). However, all groups containing 12.5% w/w K18-MMA and K18-Filler had significant antimicrobial activity against *S. mutans*, *S. sanguinis*, and *C. albicans* with reductions of 46% to 64%, 49% to 56%, and 76% to 83%, respectively. These results were partially consistent with the results of a study of poly

(2-tert-butylaminoethyl) methacrylate (PTBAEMA),[21] where 10% PTBAEMA reduced *S. mutans* CFUs by approximately 32%.[21] However, the 10% PTBAEMA group did not reduce *C. albicans* CFUs.[21] In another study of quaternized dimethylaminoethyl methacrylate in Vertex denture acrylic,[24] 12% w/w quaternized dimethylaminoethyl methacrylate reduced *C. albicans* adhesion, killing >99% of *C. albicans, E. coli, and S. aureus*, but mechanical properties were significantly compromised.[24] Finally, QAMS-PMMA demonstrated significant antimicrobial activity against *S. mutans* with as little as 0.4% w/w QAMS. However, the 12.5% w/w K18-MMA resins without K18-Filler used in the present study, which would be equivalent to having 3.75% w/w QAMS, did not show significant antimicrobial activity against *S. mutans*. K18-Filler was needed for antimicrobial activity.

The mechanism of action of the antimicrobial activity in the present study should be similar to that of the QAMS-PMMA, with the lipophilic -$C_{18}H_{37}$ alkyl chain piercing bacterial cell membranes and inducing cell lysis.[27] Specifically, while QAMS-PMMA did not inhibit *S. mutans* adhesion to the pellicle-coated acrylic resin surfaces, it significantly reduced live bacteria within the biofilms ($P<.05$). For *C. albicans*, QAMS-PMMA prevented the formation of biofilms by inhibiting *C. albicans* adhesion.[27] Further research is needed to determine the effects of K18-containing 3D printable denture resins on biofilm formation and persistent bacteria and also after treatment with saliva to confirm their mechanism of action; however, it is expected to be similar to that of QAMS-PMMA. Like the QAMS-PMMA resins, the K18-containing 3D printable denture base resins were more effective against *C. albicans* than *S. mutans*, with the 12.5% K18-MMA with no K18-MMA group demonstrating significant antimicrobial activity against *C. albicans* ($P<.05$) but not against *S. mutans*.

In the present study, the significant decrease in antimicrobial activity for *C. albicans* in addition to bacteria for all the 12.5% K18-MMA and K18-Filler-containing groups, while maintaining a modulus comparable with that of the control, is important since *C. albicans* is the leading cause of denture stomatitis and cocolonization with bacteria can lead to an increased risk of pneumonia.[12,13] The UTS of the group with 12.5% K18-MMA did decrease but by less than 10%. Thus, there is potential for the successful use of K18-MMA and K18-Filler in developing an antimicrobial 3D printable denture material.

Finally, all the components used in the present study, including K18, have been approved by the FDA, and a randomized clinical trial has shown that antimicrobial QAMS-PMMA[26] is antimicrobial and does not harm the oral mucosa or systemic health of the patient.[26] However, the biocompatibility of these K18-containing resins still needs to be determined with tests for cytotoxicity, genotoxicity, delayed-type hypersensitivity, oral mucosa irritation, and pulp and dentin response.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The possibility of using K18-MMA and K18-Filler to develop an antimicrobial denture base material was demonstrated.
2. The incorporation of K18-MMA and K18-Filler produced 3D printable denture materials with comparable polymerization properties and significant antimicrobial properties against *S. mutans, S. sanguinis*, and *C. albicans*.
3. However, high concentrations of K18-MMA and K18-Filler induced significant color shifts that made the resins whiter, and, while the moduli were comparable with that of the control resin, the ultimate strengths were lower. Thus, further research is needed to improve the esthetics and strength of these resins.

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