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Evaluation of a Novel Adhesive Barrier Film for Dental Infection Control

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Abstract: Dental units are essential devices in dental practice, and they are easily contaminated by contact with the fingers of medical personnel and patients. The effectiveness of an adhesive barrier film (PITA TECH®, Asahi Kasei Home Products Corp, Japan) intended for infection control in medical institutions for preventing dental unit contamination was evaluated. Measurements of ATP levels, reflecting contamination, were made at a dental unit table handle covered with PITA TECH® and two control sites, one covered with a PVDC resin food wrap and the other the bare silicone rubber of the handle. The coefficient of dynamic friction was also measured. The surface free energy (SFE) values of the silicone rubber, the food wrap, and PITA TECH® were calculated from contact angle measurements. The ATP value for PITA TECH® was significantly lower than that for the silicone rubber. The coefficient of dynamic friction of PITA TECH® was significantly lower than that of the food wrap and the silicone rubber. The mean SFE was 30.4 mJ/m^2 for PITA TECH®, 51.2 mJ/m^2 for the food wrap, and 13.7 mJ/m^2 for the silicone rubber, and the differences among them were all significant. PITA TECH® may offer one strategy as a simple, effective means of infection control.

Key words: barrier film ／ dental infection control ／ standard precautions ／ surface free energy

Introduction

To reduce the risk of infection by pathogens and their dissemination, a standard precaution is to treat the patient's bodily fluids (other than sweat), blood, secretions, excretions, affected skin, and mucosa as infectious.[1] This standard precaution attracted renewed attention during the COVID-19 pandemic. Dental and oral surgical care faces specific issues; namely: (1) there are many opportunities for contact with the oral mucosa; (2) large amounts of droplets containing saliva and blood are dispersed by rotary drills and ultrasound scalers on a daily basis; and (3) the injection needles used with local anaesthetics and sharp steel instruments are in frequent use. Under these conditions, there is a risk of cross-infection, as well as a risk of infection of medical personnel as a result of needle stick or exposure to blood or bodily fluids, and standard precautions should therefore be rigorously enforced. To reduce the burden on medical personnel, however, it is preferable that these precautions be simple and efficient.

Dental units are essential devices in dental practice, and they are easily contaminated by contact with the fingers of medical personnel and patients. Since they are equipped with rotating drills, spittoons for saliva, and dental suction systems, they are easily contaminated by droplets containing saliva and/or blood, with the risk of becoming a breeding ground for cross-infection.[2] Contaminants containing saliva, blood, bacteria, or viruses are sprayed into dental treatment rooms as aerosols, and they

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have been shown to pose a major problem for the consideration of measures to prevent environmental contamination.[3, 4] In fact, one study found that aerosols contaminated with blood were detected at a distance of 100 cm from the operating field during extraction procedures involving the use of rotary drills.[5] The complex construction of dental units means that some areas are easily missed when they are wiped down for cleaning and disinfection, and the effect of disinfectants on their materials is also a matter of concern. The Centers for Disease Control and Prevention (CDC) guidelines therefore recommend that high-touch surfaces of dental units (control switches, table handles, shadowless lamp handles) and contact areas of rotary drills and dental suction systems be wrapped in barrier film, and that this barrier film be replaced between each patient.[2]

Since almost no commercially available barrier films are specifically designed for infection control, in practice the majority of medical institutions make use of barrier films intended for food or industrial use. However, not all barrier films have the same properties, and their performance is bound to vary. As far as we have been able to ascertain from PubMed searches, no published study has addressed the performance of barrier film for infection control in either medicine or dentistry.

In this study, an adhesive barrier film (PITA TECH®, Asahi Kasei Home Products Corp, Tokyo, Japan) released in Japan in 2018 as a barrier film for high-touch surfaces in medical institutions was used, and its effectiveness in preventing dental unit contamination was evaluated using the adenosine triphosphate (ATP) measurement method. The coefficient of dynamic friction and contact angle were measured to evaluate slipperiness and wettability, which are two of the basic properties of PITA TECH®, and the surface free energy (SFE) was calculated from contact angle measurements to investigate the reason for the difference in ATP levels found in this study.

Materials and methods

Adhesive barrier film

PITA TECH® is a polyvinylidene chloride (PVDC) film developed as a barrier film for high-touch surfaces in medical institutions. It is soft, strong, and transparent, with the appropriate level of adhesiveness, as well as stable when treated with disinfectants such as alcohol and sodium hypochlorite. It is also impermeable to blood and microorganisms (data not shown). PITA TECH® was used as the barrier film in this study.

Dental unit ATP measurements

The measurement site was the dental unit table handle (made of silicone rubber). Measurements ($n=15$) were made at one site covered with PITA TECH® and two control sites, one covered with a PVDC resin food wrap (NEW Krewrap®, KUREHA Corp, Tokyo, Japan) and the other on the bare silicone rubber. The handle was divided into three zones, one wrapped with PITA TECH®, one wrapped with the food wrap, and one that was left bare, and environmental contamination was simulated using ATP Standard Reagent (CheckLite® ATP Eliminating Kit, Kikkoman Corp, Tokyo, Japan) adjusted to a concentration of 2×10^{-8} M after confirming the ATP level of each site was 10 or less. The ATP standard reagent was applied to each site with a sterile cotton swab that was wiped backwards and forwards 10 times, and then 5 min later, the site was wiped backwards and forwards once with a surface disinfectant wipe (Saracide Sanitizing Wipes®, Saraya Co., Ltd, Osaka, Japan). After a further 10 min, the ATP level in relative light units (RLU) was measured at each site with an ATP luminometer (Lumitester PD-30®, Kikkoman Corp.) (Figure 1).

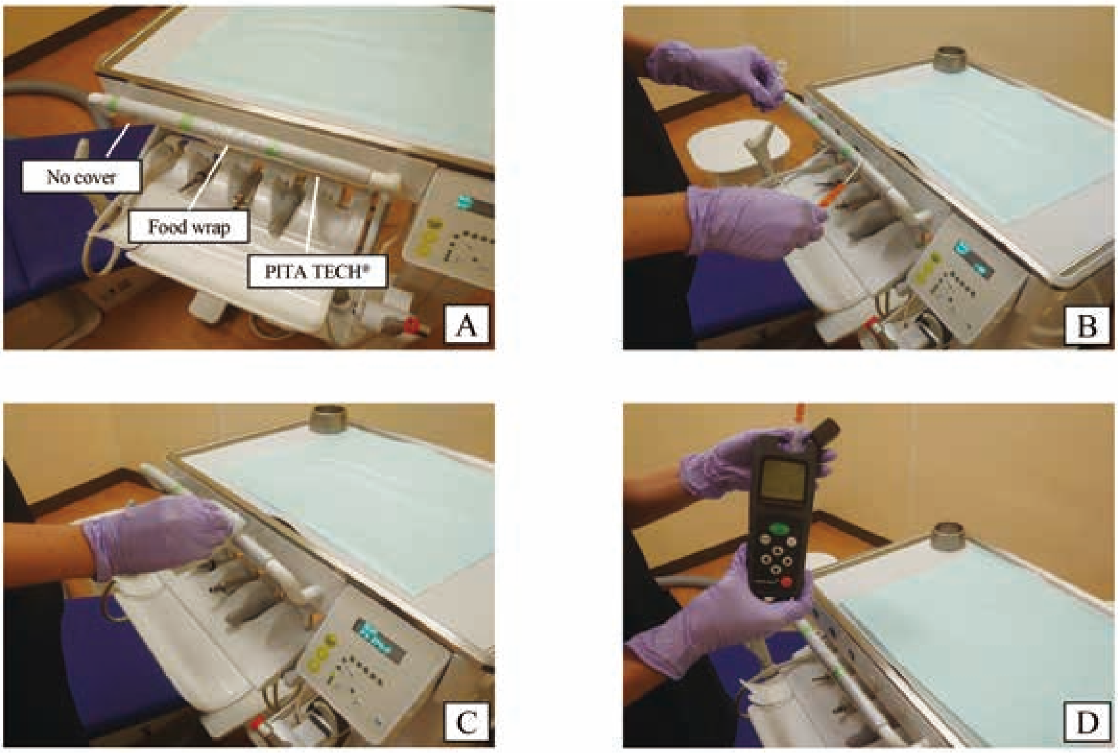

Figure 1. ATP measurements on the dental unit
The table handle of the dental unit is divided into three zones: one wrapped with PITA TECH®, one with food wrap, and one with no wrapping (silicone rubber) (A). ATP Standard Reagent adjusted to a concentration of 2×10^{-8} M is applied to each zone by wiping backwards and forwards 10 times (B). Five minutes later, the site is wiped backwards and forwards once with a surface disinfectant wipe (C). After a further 10 min, the ATP level in each zone is measured (D).

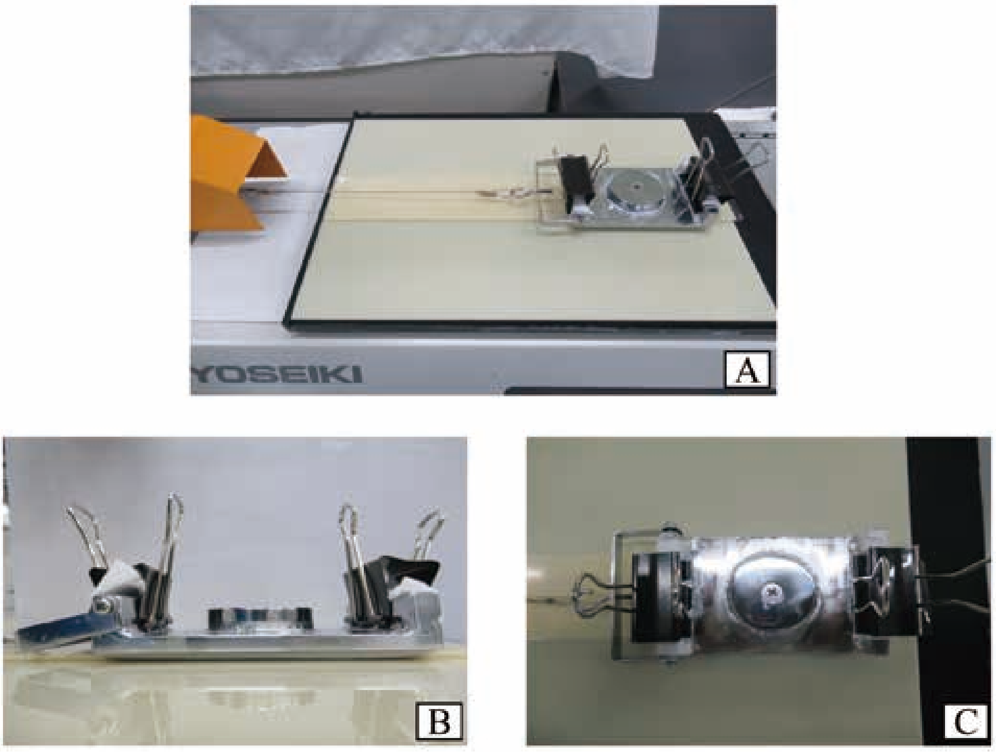

Figure 2. Coefficient of dynamic friction measurements for slipperiness evaluation
Silicone rubber, food wrap, and PITA TECH® are stuck to a 48-mm-wide ABS plastic board, and the coefficient of dynamic friction of each is measured with a friction tester (A). Magnified lateral photograph of the metal rider above the ABS board to which a surface disinfectant wipe is fixed with a clip (B). Magnified photograph of the upper surface of the metal rider in A (C).

Coefficient of dynamic friction measurements for slipperiness evaluation

To evaluate the ease with which the surface disinfectant wipes used in our hospital slid over the silicone rubber, food wrap, and PITA TECH® covering the dental unit handle, the coefficient of dynamic friction was measured by the following method. Silicone rubber, food wrap, and PITA TECH® were stuck to a 48-mm-wide acrylonitrile butadiene styrene (ABS) plastic board, and the coefficient of dynamic friction of each with respect to surface disinfectant wipes was measured with a friction tester (TR-2®, Toyo Seiki Seisaku-sho, Ltd, Tokyo, Japan) (n = 10). A new surface disinfectant wipe was used for each measurement (Figure 2).

Calculation of surface free energy from contact angle measurements

Just as a liquid possesses surface tension due to intermolecular forces, solids also contain a force that tries to minimize the surface area as a result of intermolecular forces. The surface tension acting on solids is known as surface free energy (SFE).[6] The lower the SFE, the lower the wettability of a liquid adhering to that solid, and the less likely it is that a liquid will adhere to the solid. No method exists for the direct measurement of SFE, which lacks fluidity.[7] It is therefore derived by measuring the contact angles with the solid in question of two or more liquid reagents with known physical properties, and using the values of the physical properties of the liquids and the measured contact angles to calculate the SFE. The concept of deriving the SFE from contact angle measurements is used not just in industrial fields, but also for the evaluation of dental biomaterials.[8] The Owens-Wendt-Rabel-Kaelble (OWRK) method is one of the most widely used methods for deriving the SFE of a solid.[7, 9, 10] After a drop of liquid falls onto the surface of a solid, when it stops expanding and equilibrium is reached, the Young equation [Eq. (1)] holds.[6]

$$\gamma_s = \gamma_{sl} + \gamma_l \cos\theta \quad (1)$$

Here, γ_s is the SFE of the solid, γ_{sl} is the surface tension on the solid-liquid interphase, γ_l is the surface tension of the liquid, and θ is the contact angle. Normally, because γ_{sl} cannot be measured directly, γ_s cannot be calculated by measuring θ alone. The Owens-Wendt equation [Eq. (2)] is therefore used to ascertain γ_{sl}.

$$\gamma_{sl} = \gamma_s + \gamma_l - 2\left(\sqrt{\gamma_l^d \gamma_s^d} + \sqrt{\gamma_l^p \gamma_s^p}\right) \quad (2)$$

Using Equation (2), γ_{sl} is calculated from the values of γ_s and γ_l, and their respective dispersion constituents (*d*) and polar constituents (*p*). From these two equations, the following equation, known as OWRK, is obtained [Eq. (3)].

$$(1 + \cos\theta)\gamma_l = 2\sqrt{\gamma_l^d \gamma_s^d} + 2\sqrt{\gamma_l^p \gamma_s^p} \quad (3)$$

To determine γ_s from Equation (3), θ must be measured using two types of liquid for which the dispersion constituent γ_l^d and polar constituent γ_l^p are both known. In this study, automatic contact angle meters (DM-501®, Kyowa Interface Science Co., Ltd, Saitama, Japan) were used to measure the contact angles with the silicone rubber, the food wrap, and PITA TECH® ($n = 10$) of pure water (TRUSCO NAKAYAMA Corp, Tokyo, Japan), which has a high polar constituent, and diiodomethane (KANTO CHEMICAL Co., INC, Tokyo, Japan), which has a high dispersion constituent, both of which are routinely used in the OWRK method (Figure 3). The OWRK method was then used to derive the SFE of the silicone rubber, the food wrap, and PITA TECH®.

Data analysis

SPSS® Statistics version 28 (IBM Corp, Chicago, IL, USA) was used for statistical analysis, means were calculated, and comparisons were conducted using one-way ANOVA and Bonferroni's multiple comparison test, with $p < 0.05$ regarded as significant.

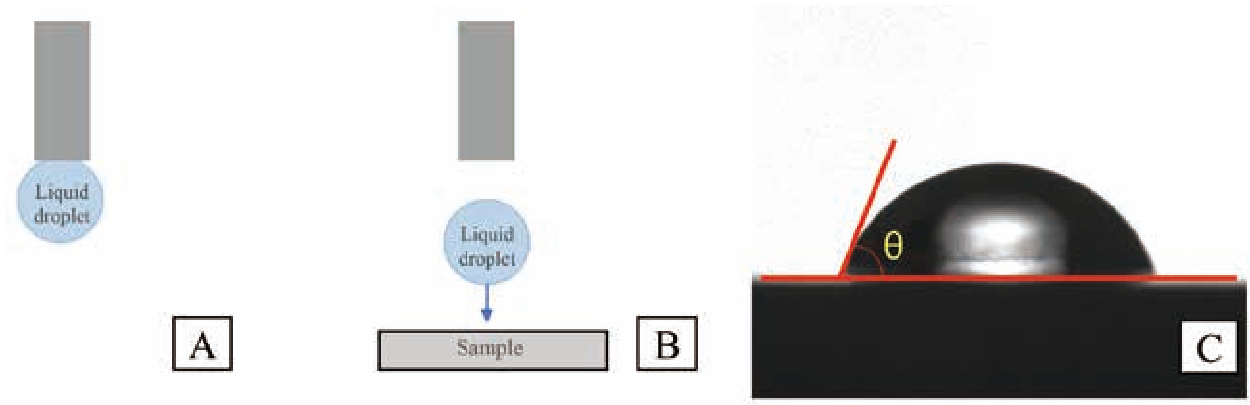

Figure 3. Procedure for contact angle measurement with an automatic contact angle meter
A 2-μL liquid droplet (pure water or diiodomethane) is produced at the tip of the nozzle (A). The liquid droplet is dropped onto the silicone rubber, food wrap, or PITA TECH® (B). A photograph is taken 1 sec after the liquid droplet has been dropped, and the contact angle between the droplet and the solid is measured (C).

Results

Dental unit ATP measurements

The mean ATP value was 77 RLU for PITA TECH®, 110 RLU for the food wrap, and 124 RLU for the silicone rubber. The mean ATP value of ATP standard reagent adjusted to a concentration of 2×10^{-8} M was 2896 RLU. The ATP value for PITA TECH® was significantly lower than that for the silicone rubber ($p < 0.05$), but the difference between the food wrap and the silicone rubber was not significant ($p > 0.05$) (Figure 4).

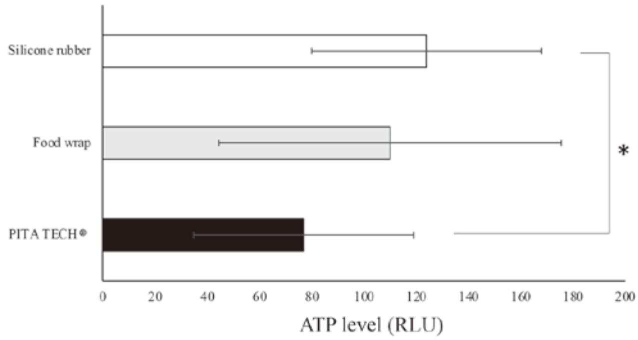

Figure 4. Dental unit ATP measurements
The mean ATP value is 77 RLU for PITA TECH®, 110 RLU for the food wrap, and 124 RLU for the silicone rubber. Data represent means ± SD of 15 determinations. $^{*}p < 0.05$.

Coefficient of dynamic friction measurements for slipperiness evaluation

The mean coefficient of dynamic friction was 0.30 for PITA TECH®, 0.48 for the food wrap, and 0.57 for the silicone rubber. The coefficient of dynamic friction of PITA TECH® was significantly lower than of the food wrap and the silicone rubber ($p < 0.05$), and that of the food wrap was significantly lower than that of the silicone rubber ($p < 0.05$) (Figure 5).

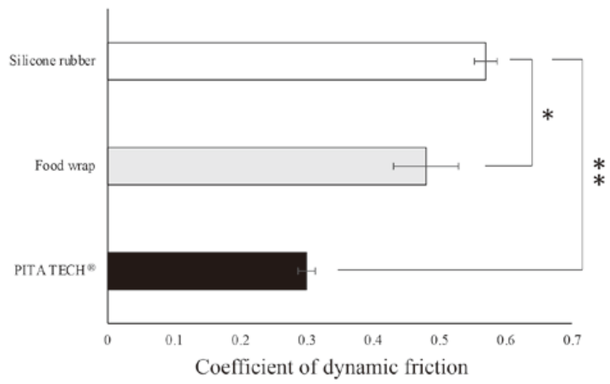

Figure 5. Coefficient of dynamic friction measurements for slipperiness evaluation
The mean coefficient of dynamic friction is 0.30 for PITA TECH®, 0.48 for the food wrap, and 0.57 for the silicone rubber. Data represent means ± SD of 10 determinations. $^{*}p < 0.05$, $^{**}p < 0.05$.

Calculation of surface free energy from contact angle measurements

Figure 6 shows the shapes of the liquid droplets (pure water and diiodomethane) on the PITA TECH®, the food wrap and silicone rubber

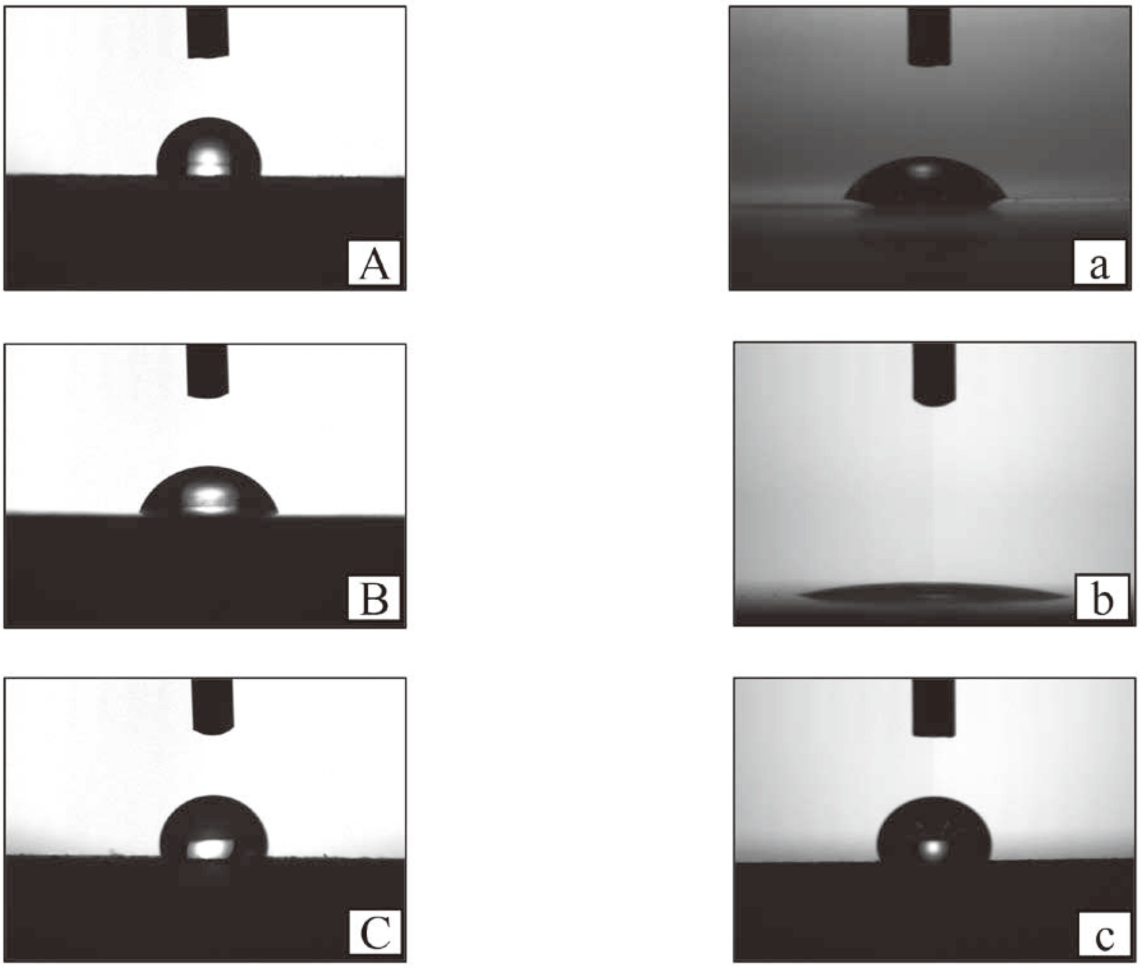

Figure 6. Shapes of the liquid droplets during contact angle measurements with an automatic contact angle meter
The photographs show a pure water droplet on PITA TECH® (A), food wrap (B), and silicone rubber (C) and a diiodomethane droplet on PITA TECH® (a), food wrap (b), and silicone rubber (c).

Table 1. Calculation of surface free energy by measurement of the contact angle

Material	Contact angle, mean (°) n = 10		Surface free energy, mean (mJ/m^2) n = 10	p value
	Pure water	Diiodomethane		
PITA TECH®	99.5	57.0	30.4	
Food wrap	68.9	15.2	51.2	< 0.05
Silicone rubber	103.5	91.2	13.7	

during contact angle measurements. The mean contact angle for pure water was 99.5° on PITA TECH®, 68.9° on the food wrap, and 103.5° on the silicone rubber. The mean contact angle for diiodomethane was 57.0° on PITA TECH®, 15.2° on the food wrap, and 91.2° on the silicone rubber. The mean SFE calculated by the OWRK method was 30.4 mJ/m^2 for PITA TECH®, 51.2 mJ/m^2 for the food wrap, and 13.7 mJ/m^2 for the silicone rubber, and the differences among them were all significant ($p < 0.05$) (Table 1).

Discussion

PITA TECH® consists of more than 90% PVDC resin, and it possesses appropriate adhesiveness and detachability, while being soft, strong, transparent, stable with respect to disinfectants, and impermeable to water, blood, and microorganisms. PVDC resin is a versatile substance that is also used in food wrap, including the food wrap used as a control in this study. The thickness of food wrap is generally around 10 μm, and there are major concerns about its strength and durability for use as a barrier film on high-touch surfaces. The thickness of PITA TECH® is around 40-50 μm, giving it the durability appropriate for a barrier film on high-touch surfaces. The manufacturer therefore recommends that PITA TECH® be replaced at intervals of up to 1 week, which has the great advantage of reducing the burden on medical personnel covering high-touch surfaces with barrier film. When food wrap is used as a barrier film for high-touch surfaces in medical institutions, it has the disadvantage of being too adhesive, so that the film sticks together and does not lie flat, instead forming a surface with numerous irregularities. This disadvantage is a major impediment to typing on the keyboards of medical terminals, and interferes with the operability of medical devices and the visibility of the information on medical monitor screens. PITA TECH® is designed to prevent such interference from occurring.

ATP is a chemical substance that is used as an energy source by living organisms. Because ATP is always present at sites of biological activity, such as in blood or bodily fluids that contain bacteria or cells, it provides a good marker of microorganism viability and contamination.[11] The ATP bioluminescence assay uses a luminometer to measure the biological luminescence reaction between ATP and luciferase. It immediately measures the amount of ATP contained in a sample, and it is used as a means of assessing cleanliness levels in the food industry and hospitals.[12, 13]

In this study, a simulated contaminated environment was set up on the table handle of a dental unit, one of its high-touch surfaces, and the ATP level was measured after wiping it clean. The food wrap did not make a significant difference compared with the silicone rubber, but the ATP level on PITA TECH® was significantly lower than that on the silicone rubber. This indicated that wiping a surface clean can be more effective for PITA TECH® than for food wrap, and it may require being wiped down fewer times than food wrap. This could be an advantage not just for dental infection control, but also in terms of medical economics and the burden on dental personnel. PITA TECH® and food wrap are both made of the same base material, PVDC, and to investigate the reason for the difference in ATP levels found in this study, an attempt was made to scan their surface microstructures by scanning electron microscopy. However, both the food wrap and PITA TECH® are so thin that specimens cannot be properly prepared for scanning due to technical problems, and scanning electron microscopy was therefore not feasible. Consequently, it was decided to measure the coefficient of dynamic friction and SFE to evaluate their surface structures in mechanical terms.

The mean coefficient of dynamic friction of an environmental cleaning cloth was 0.30 for PITA TECH®, 0.48 for the food wrap, and 0.57 for the silicone rubber, and the differences among them all were significant. These coefficients of dynamic friction show how easy it was for the environmental cleaning cloth to slide over each of the measurement specimens, with a lower coefficient of kinetic friction indicating that the cloth slid more easily. The dental unit table handle is covered with silicone rubber to make it easier for dental personnel to grip, and it is thus logical that this substance had the highest coefficient of dynamic friction. The difference between the coefficients of dynamic friction of the PITA TECH® and the food wrap suggested that the former may be easier to wipe clean, with less likelihood of material being left behind. This difference in the coefficient of dynamic friction despite the fact that both PITA TECH® and the food wrap are made of the same basic material, PVDC resin, may have been due to differences in their smoothness, additives, adhesives, and releasing agents.

Blood and saliva are dispersed in both dental and oral surgical practice, and to reduce the risk of cross-infection, a barrier film used for dental infection control must be resistant to the adhesion of blood or saliva containing microorganisms. The lower the SFE of a solid, the lower is its wettability with an adhering liquid, and the more difficult it is for liquids to adhere to it.[8] Barrier films used for dental infection control should therefore have a low SFE, but since an excessively low SFE might make equipment more difficult for medical personnel to handle, it may be important to strike a balance between wettability and manipulability. The SFE values identified in this study were 30.4 mJ/m^2 for PITA TECH®, 51.2 mJ/m^2 for the food wrap, and 13.7 mJ/m^2 for the silicone rubber, with the value for PITA TECH® significantly lower than that for the food wrap. The silicone rubber had the lowest SFE, which might suggest that it should have had the lowest ATP value after cleaning, but the opposite result was found, raising the question of why it exhibited the highest ATP value. The reason may have been that the coefficient of dynamic friction of the silicone rubber with respect to the surface disinfectant wipes was higher than those of PITA TECH® and the food wrap, reducing the ease with which the surface disinfectant wipes slid over the surface and leading to more material being left behind. Although it was not possible to verify this in the present study, the surface of silicone rubber has a tendency to develop tiny irregularities and cracks[14], and they may have trapped the residual ATP reagent.

Conclusion

The originality of this study lies in its focus on barrier films for infection control in dental practice. The COVID-19 pandemic has led to an increased emphasis on infection control in dentistry, but the increased burden on dental personnel due to this intensification of infection control poses its own problems. PITA TECH® may be easier to wipe clean, and offer one strategy as a simple, effective means of infection control that does not increase the burden on dental personnel.

Conflicts of interest

None of the authors reported any conflicts of interest.

A statement of institutional review board approval or waiver

Not required.

Acknowledgments

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歯科感染制御のための新規接着性バリアフィルムの評価

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要旨：歯科医療において歯科ユニットは必須の器械であり，医療従事者や患者の手指接触による汚染が生じやすい。本研究では医療機関での感染制御を目的にした接着性バリアフィルム（ピタテック®，旭化成ホームプロダクツ株式会社）を使用し，歯科ユニット汚染に対する有用性を検討した。歯科ユニットのテーブルハンドル（シリコンゴム）をATP測定法による汚染度の評価部位とし，試験群としてピタテック®，対照群として塩化ビリニデン系樹脂の食材用ラップ，シリコンゴム（ラップなし）を設定した。ピタテック®の基礎的性能である滑り性と濡れ性を評価するために，動摩擦係数と表面自由エネルギーも同じ試験群と対照群で測定した。表面自由エネルギーは液体試薬との接触角を測定することにより算出した。ATP測定についてはピタテック®がシリコンゴムに比較して有意に低い値を示した。動摩擦係数についてはピタテック®が食材用ラップとシリコンゴムに比較して有意に低い値を示した。表面自由エネルギーの平均はピタテック®30.4 mJ/m^2，食材用ラップ51.2 mJ/m^2，シリコンゴム13.7 mJ/m^{2}であり，全ての群間に有意差を認めた。ピタテック®は簡便で効率的な歯科感染制御の方策として期待ができる。

索引用語：　バリアフィルム　／　歯科感染制御　／　標準予防策　／　表面自由エネルギー

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