By utilizing the mixed-ligand method, two novel metal-organic frameworks (MOFs) based on Zn(II) ions as nodes with the chemical formulae of $\text{[Zn}_{2.5}(\text{abta})(\text{trz})_{2}(\text{H}_{2}\text{O})]_{n} \cdot 3\text{H}_{2}\text{O}$ (1, $\text{Htrz} = 1\text{H}-1,2,4\text{-triazole}$) and $\text{[Zn}_{3}(\text{abta})_{2}(\text{bibb})_{2}]_{n}$ (2, $\text{bibb} = 1,4\text{-bis(benzimidazol-1-yl)-2-butene}$) were produced via $\text{Zn(NO}_{3}\text{)}_{2}\cdot 6\text{H}_{2}\text{O}$ reacting with the 1-aminobenzene-3,4,5-tricarboxylic acid ($\text{H}_{3}\text{abta}$) in the existence of distinct nitrogen-donor co-ligands. The different N-donor ligands result in their distinct framework structures, and the compound 1 with higher solvent accessible void and large window size shows highly heterogeneous catalytic activities for Knoevenagel condensation. The treatment of Staphylococcus aureus biofilms formation during spine surgery incision infection and the related mechanism was explored at the same time. First of all, the $\text{S. aureus}$ bacterial numbers in the infectious site was measured under compound 1 or 2 treatment. In addition to this, the relative expression levels of the genes related with $\text{S. aureus}$ biofilms was determined with real time RT-PCR.

**Introduction**

With the continuous development of medical technology, many spinal diseases can be treated by surgery, and the complications brought by spinal surgery have been paid more and more attention. Spine surgery incision infection (SSI) is one of the common complications of spinal surgery, with an incidence rate of 0.7%–12% reported in the literature [1, 2]. SSI not only affects the patient’s surgical results, but also causes medical burden of patients. *Staphylococcus aureus* is commonly found in healthy human skin, and is the...
most common pathogenic infection factor of early surgical site infections after spinal surgery [3, 4]. Staphylococcus aureus easily forms bacterial biofilms, which greatly increases the difficulty of anti-infective treatment.

Metal-organic framework (MOFs), which is consisted of organic ligands and metal ions, have a designable structure, adjustable functional application, and unique flexibility, offering a distinctive opportunity for the development of novel functional materials to investigate the basic nano molecular assembly in the limited environment [5–7]. In the recent decade, because of the diversiform applications of MOFs in nonlinear optics, gas adsorption, catalysis, magnetism, luminescence, conductivity and so on, the design as well as the generation of MOFs have aroused extensive interest [8–12]. In principle, the assembly for the MOFs is affected via many factors, for instance the conditions of reaction, anion properties, the metal ions coordination geometry, flexibility of ligands, coordination patterns, solvent and temperature, etc [13, 14]. In these elements, the coordination geometry for the central metal ions, the coordination patterns and flexibility of the ligands have well proved that they can control the interpenetration, pore size and structure topology of MOFs, thus leading to the structural diversity and associate performances of MOFs. On the basis of this concept, crystal materials with clear definition are constructed via using appropriate organic spacers possess functional groups of the bridging metal center, which has developed rapidly in the fields of coordination chemistry and crystal engineering, materials science as well as supramolecular chemistry [15–17]. A skeleton possesses long spacer ligands can interweave with other networks to generate interpenetrating structures [18, 19]. In this regard, using a small and rigid organic ligand as the auxiliary ligand in the mixed-ligand system might be helpful for the formation of MOFs with robust framework and large porosity. Bearing these in mind, in this work, by utilizing the mixed-ligand method, two novel metal-organic frameworks (MOFs) based on Zn(II) ions as nodes with the chemical formulae of \([\text{Zn}_{2.5}(abta)(trz)_2(H_2O)]\cdot C_1_3H_2O\) \(_n\) (1, Htrz = 1H-1,2,4-triazole) and \([\text{Zn}_3(abta)_2(bibb)_2]\) \(_n\) (2, bibb = 1,4-bis(benzimidazol-1-yl)-2-butene) were produced via \(\text{Zn(NO}_3\text{)}_2\cdot 6\text{H}_2\text{O}\) reacting with the 1-aminobenzene-3,4,5-tricarboxylic acid (H\(_3\)abta) in the existence of distinct nitrogen-donor co-ligands. The different N-donor ligands result in their distinct framework structures, and the compound 1 with higher solvent accessible void and large window size shows highly heterogeneous catalytic activities for Knoevenagel condensation. The catalytic products were determined through the equipment of gas chromatograph which has FID detector (GC-2014C, Shimadzu, Japan) and capillary tube (30 m long × 0.25 mm inner diameter, WondaCAP 17). Their treatment activity against \(S. \text{aureus}\) biofilms formation during spine surgery incision infection was detected and the related mechanism was assessed at the same time. The results of the \(S. \text{aureus}\) CFU determination indicated that compared with compound 2, compound 1 could enhance the anti-bacterial activity of the penicillin, which is even better than other MOF materials. Besides, the data of the real time RT-PCR strongly suggested that compound 1 could significantly inhibited the \(S. \text{aureus}\) biofilms genes expression, but not compound 2.

**Experimental**

**Chemicals and measurements**

All the ligand and metal salts used in this study were obtained from Jinan Henghua Sci. & Tec. Co. Ltd. And the other materials utilized in this research could be bought from commercial sources and they could be utilized with no purification. Carbon, nitrogen and
hydrogen were analyzed with the elemental analytical instrument of Vario MACRO cube. The IR spectrum of KBr pellets between 4000 and 400 cm$^{-1}$ were carried out by using the FTIR–8400S Spectrometer. The measurements of powder X–ray diffraction were performed with the diffractometer of Rigaku D/Max–2500 PC in 5–50$^\circ$ 20 range with radiation of Cu K$\alpha$ ($\lambda = 0.71073$ Å). On the analyzer of ZCT–A at 25–800°C, the thermogravimetric (TG) analyses were carried out in nitrogen atmosphere with 10°C·min$^{-1}$ heating rate.

**Preparation and characterization for \([Zn_{2.5}(abta)(trz)(H_2O)]\cdot3H_2O\)\(_n\) (1) and \([Zn_3(abta)_2(bibb)]\)\(_2\)\(_n\) (2)**

For the compound 1, we mixed H$_3$abta of 0.022 g and 0.1 mmol, Htrz which is 0.014 g and 0.2 mmol, Zn(NO$_3$)$_2$·6H$_2$O of 0.089 g and 0.3 mmol, Na$_2$CO$_3$ which is 0.021 g and 0.2 mmol, water of 3 mL to form a mixture, and put the obtained mixture into a vial of 7 mL and then heated it for 72 h to 80°C. We acquired colorless crystals with a yield of 52.6% based on the H$_3$abta ligand used. Element analysis (%) found (calcld.) for 1 (C$_{13}$H$_{16}$N$_7$O$_{10}$Zn$_{2.5}$): C 25.11 (25.02), H 1.95 (2.25), N 15.77 (15.72).

For the compound 2, we mixed Zn(NO$_3$)$_2$·6H$_2$O of 0.089 g and 0.3 mmol, bibb which is 28.8 mg and 0.1 mmol, H$_3$abta of 0.1 mmol and 0.022 g, NaOH which is 24.0 mg and 0.6 mmol and 10 mL distilled water to generate a mixture, and sealed the acquired mixture into the 25 mL stainless container lined with Teflon. Then we heated the obtained mixture from the ambient temperature to 140°C for three days and cooled it to the ambient temperature with 5°C·h$^{-1}$ rate. We acquired colourless crystals with block-shape of compound 2 and dried it in air. The yield is 47.3% (on the basis of bibb). Element analysis calcld. for 2 (C$_{36}$H$_{20}$N$_6$O$_{16}$Zn$_3$): C 43.73, H 2.04, N 8.50%. Found: C 43.58, H 2.17, N 8.32%.

With the diffractometer of Oxford Xcalibur E we obtained the data of X-ray. The software of crysalispro was applied to analyze the strength data and convert the strength data into the HKL files. The program of SHELXS inaccordance with direct method was utilized to build the initial framework model for the compound 1, and the program of SHELXL-2014 inaccordance with least square means was modified. Mixing anisotropic parameters with 1’s non-H atoms. Then all of the hydrogen atom via applying the AFIX command to geometrically fix on the C atom they are bridged to. Table 1 details the crystallographic parameters as well as the refinement of these two compounds.

**Bacterial CFU determination**

To evaluate the treatment activity of compounds 1 and 2, the bacterial CFU determination was performed in this present research. The rat infection model was established in this research before the treatment. This experiment was performed under the guidance of the instruments with some modifications. In brief, 60 male SD rats used in this research were purchased from the Nanjing University Model Animal Research Center (Nanjing, China). All the animals were placed at the standard condition of 20 to 25°C and 45% humidity. All the performances in this research were approved by the Affiliated Hospital Ethics Committee of Nanjing University (Nanjing, China). Before the conduction, all rats were divided into five distinct groups, the control group, model group, penicillin treatment group, penicillin + compound 1 treatment group, penicillin + compound 2 treatment group and related material (Ref 1) treatment group. For the construction of SSI infection model, 30 m/kg sodium pentobarbital were injected into animals for anesthesia.
Then, the 2–4 cm surgical incision was performed on the animal spine sides. The penicillin with or without compounds was used for indicated treatment. Subsequently, the tissue in the infectious site was collected for the bacterial colonies’ determination with agar plates methods. This experiment was carried out three times and the results were expressed with mean ± standard deviation.

**Real time RT-PCR**

The real time RT-PCR was further conducted in this research for the evaluation of compounds 1 and 2’s inhibition against the *S. aureus* biofilms genes expression. This experiment was carried out totally according to instructions’ instructions with a little modification. Briefly, the *S. aureus* bacterial cells were cultured in tryptic soy broth (TSB) medium + 0.5% glucose in an incubator at 37 °C. Then, compound 1, compound 2 and Ref 1 was added into wells combined with penicillin for 24 h and 48 h treatment. After the treatment, the *S. aureus* bacterial cells were collected, washed with PBS. The TRIzol Reagent (Sigma, St. Louis, MO, USA) was used for the total RNA extraction. The RNA was reversely transcripted into the cDNA through the RNA reverse transcription kit after measuring the quantity as well as quality of RNA in the *S. aureus* bacterial cells. Ultimately, the expression of *S. aureus* biofilms genes was measured with RT-PCR. The results were acquired from three performs via utilizing $2^{-\Delta\Delta Ct}$ approach. This conduction was performed at least three times.

**Results and discussion**

**Molecular structure**

Colorless crystals of the compound 1 were prepared via the hydrothermal reaction of Htrz, H3abta and Zn(NO3)2·6H2O in water for 72 h at 80 °C. In the air, compound 1 is stable and insoluble in MeOH, EtOH and DMF and other familiar organic solvents. On the basis of the crystal data which harvested under the room temperature, the results for

| Table 1. The crystallographic parameters as well as the refinement of the compound 1 and compound 2. |
|---------------------------------------------------------------|
| Identification code | 1 | 2 |
| Empirical formula | C_{26}H_{20}N_{14}O_{14}Zn_{5} | C_{36}H_{24}N_{6}O_{12}Zn_{3} |
| Formula weight | 1079.41 | 924.69 |
| Temperature/K | 293.15 | 296.15 |
| Crystal system | monoclinic | monoclinic |
| Space group | P2_{1}/c | C2/c |
| a/Å | 11.2416(2) | 26.068(5) |
| b/Å | 18.1540(11) | 13.514(2) |
| c/Å | 12.2397(2) | 10.1274(18) |
| α/° | 90 | 90 |
| β/° | 108.553(2) | 93.375(2) |
| γ/° | 90 | 90 |
| Volume/Å³ | 2368.06(7) | 3561.5(11) |
| Z | 2 | 4 |
| ρ_cav/g/cm³ | 1.514 | 1.725 |
| μ/mm⁻¹ | 2.563 | 2.079 |
| Data/restraints/parameters | 4166/0/269 | 3636/6/258 |
| Goodness-of-fit on F² | 1.165 | 1.091 |
| Final R indexes [I>2σ(I)] | R₁ = 0.0413, wR₂ = 0.1312 | R₁ = 0.0368, wR₂ = 0.1099 |
| Final R indexes [all data] | R₁ = 0.0486, wR₂ = 0.1346 | R₁ = 0.0401, wR₂ = 0.1123 |
| Largest diff. peak/hole/e Å⁻³ | 1.81/−0.55 | 0.39/−1.53 |
| CCDC | 1990641 | 1990642 |
the structural solution as well as the refinement indicated that the compound 1 was crystallized in monoclinic P21/c space group and present a three-dimensional skeleton possesses one-dimensional channels running along c-axis. In its asymmetry unit, there are a completely deprotonated ligand abta\(^{3-}\), three absolute Zn(II) ion in crystal, two deprotonated ligand trz\(^{-}\) as well as a coordinated molecule of water (Figure 1(a)). Three kinds of Zn(II) ions with unique crystal structure of Zn3, Zn2, and Zn1 are respectively four-coordinated, six-coordinated, as well as four-coordinated. Zn1 is 4-coordinated via two oxygen atoms of carboxylate (the length of Zn-O is between 1.932(2) and 1.941(3) Å) in two ligands abta\(^{3-}\) and two N atoms in two trz (the length ofZn-N is between 1.984(3) and 2.005(3) Å). Zn2 is surrounded via two O atoms (the length of Zn-O is between 2.132(3) and 2.134(3) Å) in two ligands abta\(^{3-}\) and four nitrogen atoms (from 2.125(3) to 2.159(3) Å) in four ligands trz. Zn3 also uses distorted geometry of tetrahedron, but with distinct coordination surrounding in Zn1. Zn3 is ligated via an O atom in ligand abta\(^{3-}\) and an oxygen atom in water along with two nitrogen atoms in two ligands trz. The distances of Zn-O is between 1.932(3) and 1.997(4) Å, and the distances of Zn-N are between 1.974(3) and 1.993(4) Å, respectively. The ligand abta\(^{3-}\) is completely deprotonated and links with four neighbouring Zn(II) ions utilizing its three carboxylic acid groups in the model of \(\mu_4-(\mu_2-\eta_1; \eta_1)-(\mu_1-\eta_1; \eta_0)-(\mu_1-\eta_1; \eta_0)\) (Figure 1(b)). Three N atoms of ligands trz link three absolute Zn(II) ions to generate a two-dimensional layered skeleton, which are deep pillared through the ligands abta\(^{3-}\) to acquire a three-dimensional skeleton structure (Figure 1(c)). A remarkable structural property of compound1 is the existence of one-dimensional nanosized channels along c-axis, and the window dimension is 7.2 Å, and the

Figure 1. (a) The asymmetric unit view for the compound 1. (b) The coordination mode for the abta\(^{3-}\) anion. (c) The two-dimensional Zn-trz layered network of the compound 1. (d) Three-dimensional skeleton for the compound 1 revealing the one-dimensional channels along c-axis.
uncoordinated amido groups points to the center of channel (Figure 1(d)). The solvent accessible vacancy of the 1 was 39.9% after the coordination molecules of water and guests were removed, as shown in the PLATON software.

The study of single crystal X-ray diffraction reveals that the compound 2 was crystallized in monoclinic crystal system space group C2/c. Its asymmetric unit contains 1.5 centers of Zn(II), a ligand bibb and an anion abta$^{3-}$. There are two absolute Zn(II) atoms in crystal in the compound 2 (Figure 2(a)). Zn1 is tetracoordinated [ZnO$_3$N], in the triangular pyramid coordination surrounding of $\tau = 0.86$. The three O atoms of O3E, O6D and O1 (with the symmetry code of E: x, $-y$, z+1/2 and D: x, y, z+1) are from distinct ligands abta$^{3-}$ and the apex is held via N2 in ligand bibb. The lengths of Zn1-O bond are between 1.962(1) and 1.983(1) Å and the length of Zn1-N bond is 2.021(2) Å. The Zn2 is surrounded through six oxygen atoms in four ligands abta$^{3-}$ (O2B–O2C–O5–O5A at plane of base while O3B–O3C at axes positions, with the symmetry code of C: x, $-y$, z–1/2, B: $-x+1$, $-y$, $-z$ and A: $-x+1$, y, $-z–1/2$). The lengths of Zn2-O bond are between 2.043(1) and 2.081(1) Å. The completely-deprotonated ligands abta$^{3-}$ use as the patterns of (κ1-κ1)-(κ2-κ0)-(κ1-κ1)-µ5 (Figure 2(b)). The Zn2 ion and Zn1 ion are linked into one-dimensional chain through the ligands abta$^{3-}$, and via sharing the centers of Zn(II), the ligands bibb are further linked along diverse directions to generate a three-dimensional compound network (Figure 2(c)). The distance for the nodes of Zn1···Zn1F (with the symmetry code of F: $-x+1/2$, $-y+1/2$, $-z+2$) connected via the ligands bibb is 12.151Å. The ligands bibb utilize µ2 trans conformation, and both these two

![Figure 2. (a) The asymmetric unit view for the 2. (b) The coordination mode for the abta$^{3-}$ anion in the compound 2. (c) The three-dimensional pillar-layered network of the compound 2. (d) The four-linked skeleton view for the compound 2.](image-url)
benzimidazole rings for ligands bibb are parallel to each other. With the further analysis of topology, the framework of the compound 2 can be simplified as an uncommon (4,4,5)-linked three-dimensional network with {4².6³.8}2{4².6²}{4⁷.6³}2 Schlöffl symbol (Figure 2(d)).

To check the phase purity of the products, powder X-ray diffraction (PXRD) experiments have been carried out for these complexes (Figure 3(a)). The peak positions of the experimental and simulated PXRD patterns are in good agreement with each other, indicating that the crystal structures are truly representative of the bulk crystal products. The differences in intensity may be owing to the preferred orientation of the crystal samples [20]. The thermal stability of compounds 1 and 2 was examined by thermogravimetric (TG) analysis, with the results shown in Figure 3(b). The TGA curve shows that the weight loss of 1 before 166 °C corresponds to the removal of three uncoordinated water molecules and one coordinated water (Found: 13.1%, Calculated: 13.2%). The framework began to decompose upon further heating. The TG curve shows that complex 2 possessed a one-step weight loss process. The weight loss of 75.2% (calcd: 75.3%) is assigned to the removal of organic bibb and abta³⁻ ligands from 215 °C to 630 °C. Finally, the residual weight 24.8% (calcd: 24.7%) corresponds to ZnO.

**Knoevenagel condensation reaction**

Considering the high porosities for the compound 1, the catalytic performances for the condensation reaction of Knoevenagel were assessed on the basis of the its activated samples (denoted as 1a hereafter), which was obtained by soaking the as-prepared 1 (800 mg) in MeOH for three days and then pumped under the dynamic vacuum for one day. The yields of catalytic product was determined and calculated with the gas chromatography. As exhibited in the Table 2, in the absence of catalyst for the reaction of malondionitrile and benzaldehyde, the blank experiment showed that benzyldiene methylene nitrile was not formed. In order to determine the active center of reaction, Zn(NO₃)₂·6H₂O was applied as the homogeneous catalyst, and the conversion rate was 70%. When the compound 1a was utilized as the catalyst, 60 min later, the yield was 96% and the high turnover frequency (TOF) was 192.0 h⁻¹. For the catalyst 1, after 60 min, the yield reveals 57%, which shows the significance of sample activation to deep discuss the universality of catalyst. Under identical catalytic conditions, the expansion experiments of other benzaldehyde derivatives possess malondionitrile were performed. Here, we carried out many
reactions via utilizing the compound 1a. For the benzaldehyde derivatives which are short of electron, for instance 4-F- and the 2-Cl-, nearly entire conversions with the equivalent products were acquired (the TOF is 198.0 h\(^{-1}\)). However, for benzaldehyde derivatives possess the electron-donating groups, for instance 4-C\(_2\)H\(_5\)-, 4-CH\(_3\)-O- as well as 4-CH\(_3\)-, the yields are relatively low with the equivalent products were realized (65%, 87% and 90%, and the TOF is respectively 109.6, 146.6 and 151.7 h\(^{-1}\)). The results exhibit that the substituents on benzaldehyde possess an obvious effect against the yields of catalysis.

In order to research the effect of excessive homogeneous catalyst against the catalytic activity in 1a, we filtered and separated the organics after thirty minutes. Then stirred filtrate for another thirty minutes. As revealed in the Figure 4(a), no transformation of the benzaldehyde is found via the gas chromatography. The result confirms that catalysis is heterogeneous in fact.

In practical application, reuse and easy separation are the key parameters in the process of developing the heterogeneous catalysts. Utilizing the benzaldehyde as raw material, the stability and reusability of the compound 1a were further investigated. The content of benzylidene methacrylonitrile kept unchanged in 60 min, suggesting that the process of catalysis has been completed. The regenerated compound 1a was filtered and harvested, cleaned twice by using the methanol, dried and then used for standby. As revealed in the

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**Table 2.** The condensation reaction for Knoevenagel of malononitrile with many benzaldehyde derivatives.

| Catalyst          | Substrate | Product | Yield (%) | TOF (h\(^{-1}\)) |
|-------------------|-----------|---------|-----------|------------------|
| Blank             | [image]   | [image] | No reaction | 0                |
| Zn(NO\(_3\))\(_2\)-6H\(_2\)O | [image]   | [image] | 70        | 140              |
| 1                 | [image]   | [image] | 96        | 192              |
| 1                 | [image]   | [image] | 57        | 103              |
| 1\(_\text{Cl}\)   | [image]   | [image] | >99       | 198              |
| 1\(_\text{F}\)    | [image]   | [image] | >99       | 198              |
| 1                 | [image]   | [image] | 90        | 151              |
| 1                 | [image]   | [image] | 87        | 146              |
| 1                 | [image]   | [image] | 65        | 109              |

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Figure 4(b), the catalytic rate of regenerated compound 1a was investigated. After four cycles, the rate of conversion reduced by approximately 8%, but it still kept a high conversion rate. This suggested that compound 1a has high efficiency in the reaction of condensation and it can be regenerated directly.

It is commonly believed that zinc(II) ion is Lewis acid position, and Lewis base position is offered via uncoordinated nitrogen atom of the abta anion. In the process of catalysis, zinc(II) ions interact with the benzaldehyde carbonyl groups. At the same time, the weak Lewis base of 1a reacts with the propionitrile at nitrogen-site to form the carbon anion. Afterwards, active benzaldehyde attacked by the carbon anion species, along with the formation of dehydration and C–C bond, resulting in the generation of the benzylidemalononitrile.

**Compound inhibited S. aureus survival during SSI**

After the triumphant synthesis of compounds 1 and 2, the S. aureus CFU determination was performed to evaluate the inhibition activity for compounds 1 and 2, as well as the Ref 1 [21] against the S. aureus biofilms formation during SSI. As the results showed in Figure 5, the S. aureus CFU numbers level in model group was much higher than the control group, there was a significantly difference between these two groups. The penicillin treatment only showed a slightly inhibitory activity on the S. aureus CFU number inhibition. While, the penicillin + compound 1 combined treatment significantly reduced the S. aureus colonies in the infectious site during SSI, which is strongly than compound 2. However, the Ref 1 combined treatment has much weaker influence on the S. aureus CFU number.

**Compound inhibited the S. aureus biofilms genes relative expression level**

In the above experiment, we have revealed that compound 1 exhibited much more excellent inhibition than compound 2 on enhancing the effect of the penicillin against S. aureus CFU numbers during SSI infection treatment. However, more experiments were needed for the mechanism exploration. Thus, in this research, the expression levels of S. aureus biofilms genes, such as SarA and eae was measured with real time RT-PCR. As the results showed in Figure 6, in consistence with the previous experiment, the penicillin + compound 1 treatment could significantly reduce the eae and SarA relative
expression level in the *S. aureus*, which is much stronger than compound 2. The Ref 1 combined treatment still showed no inhibition on the *S. aureus* biofilms genes relative expression.

Figure 5. Inhibited *Staphylococcus aureus* survival during SSI after treated with compounds. SSI infection mode was constructed and then penicillin + compound 1, penicillin + compound 2 and penicillin + Ref 1 was added for indicated treatment. The CFU number determination was finished in the infectious site at least three times. All the results were expressed as mean ± standard deviation.

Figure 6. Inhibited *Staphylococcus aureus* biofilms genes relative expression level after compound treatment. *S. aureus* bacterial cells were collected and seeded into 6-well plates, followed by the penicillin + compound 1, penicillin + compound 2 and penicillin + Ref 1 treatment. The real time RT-PCR was performed to measure the relative expression of the *SarA* and *eae*. 
Conclusion

To sum up, we have triumphantly produced two novel metal-organic frameworks based on Zn(II) via Zn(NO_3)_2·6H_2O reacts with the 1-aminobenzene-3,4,5-tricarboxylic acid (H_3abta) in the existence of distinct nitrogen-donor co-ligands. The different N-donor ligands result in their distinct framework structures, and the compound 1 with higher solvent accessible void and large window size shows highly heterogeneous catalytic activities for Knoevenagel condensation. Through the S. aureus CFU determination, we confirmed that compound 1 exhibited much stronger inhibition than compound 2 on the anti-bacterial activity combined with the penicillin, which is even better than other MOF materials. In addition to this, the real time RT-PCR also suggested that compound 1 could significantly inhibited the S. aureus biofilms genes expression, but not compound 2. In conclusion, compound 1 has much stronger treatment activities than compound 2 on the S. aureus biofilms formation during spine surgery incision infection.

Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

The data used to support the findings of this study are included within the article.

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