Two Zn(II)-based Coordination Polymers: Treatment Activity on Chronic Periodontitis by Inhibiting the Relative Expression of the *Porphyria gingivalis* Survival Gene

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Abstract: Two mixed-ligand complexes on the basis of L ligand [L = 3,6-bis(imidazol-1-yl)pyridazine] have been prepared under the solvothermal reaction conditions via the Zn(II) salts reacting with the ligands of L in the existence of two positional isomerous carboxylic acid ligands and their chemical formula respectively are \([\text{Zn}_5 (L)(1,2-\text{BDC})_4 (\mu_3-\text{OH})_2 ]_n (1, 1,2-\text{H}_2 \text{BDC} = 1,2\text{-benzenedicarboxylic acid})\) and \([\{\text{Zn}_4 (L)_2 (1,3-\text{HBDC})(1,3-\text{BDC})(\mu_3-\text{OH})_4 \} \cdot \text{ClO}_4 \cdot 3\text{H}_2 \text{O}]_n (2, 1,3-\text{H}_2 \text{BDC} = 1,3\text{-benzenedicarboxylic acid}).\) The inhibitory influence of the two compounds against the inflammatory response in periodontium was evaluated by measuring the inflammatory cytokines releasing with ELISA detection kit. The results of ELISA assay indicated that compound 1 showed much stronger inhibitory influences than compound 2 against the inflammatory cytokines releasing. In addition to this, the suppression activity of the compounds against the survival gene of *Porphyria gingivalis* was detected via the real time Reverse Transcription-Polymerase Chain Reaction, and the results suggested that compound 1 could evidently suppresses the survival gene expression of *Porphyria gingivalis*, which is much better than the biological activity of compound 2. Above all, compound 1 was more outstanding than compound 2 on chronic periodontitis treatment by inhibiting the *Porphyria gingivalis* survival.

Key words: coordination polymer, solvothermal reactions, chronic periodontitis, *Porphyria gingivalis*

1 Introduction

Periodontitis refers to the chronic inflammatory disease that occurs in the periodontal supporting tissues, which can eventually cause irreversible damage to the periodontal tissues, leading to loosening and loss of teeth\(^3\). Therefore, periodontitis is also the main cause of tooth loss in adults. *Porphyromonas gingivalis* is the most dominant bacteria in chronic periodontitis.\(^2\)\(^,\)\(^3\) Thus, in our present investigation, the two compounds were designed and synthesized to treat the chronic periodontitis, and their inhibitory influences against the survival gene expression of *Porphyria gingivalis* was also determined.

Because of their unique aesthetic architectures and their latent applications in polyphase catalysis, nano-magnetism, gas capture and gas storage, biomedicine and photoluminescence and other fields, the reasonable design and the synthesis of fresh entanglement networks have aroused great interest\(^4\)\(^-\)\(^8\). Nevertheless, how to develop the efficient synthesis schemes to synthesize the coordination polymers (CPs) containing target structure and expected performances remains a major challenge for the chemists\(^9\)\(^-\)\(^11\). From the synthesis point of view, the structures of CPs can be controlled via selecting proper metal centers and the temperature of reaction, along with the organic ligands, value of pH and solvent system and other reaction conditions\(^12\)\(^-\)\(^15\). Among the above factors, due to the geometric configuration, donor atom and coordination site, flexibility and rigidity, substituent and symmetry characteristics of the bridge ligands, the design and the choice of appropriate bridge ligands are essential to the establishment of CPs\(^16\)\(^-\)\(^20\). In our present investigation, in order to explore the structural diversity of CPs on the basis of the mixed-ligand method, two mixed-ligand complexes on the basis of L ligand [L = 3,6-bis(imidazol-1-yl)pyridazine] have been pre-
pared under the condition of solvothermal reactions via the Zn(II) salts reacting with the ligands of L in the existence of two positional isomeric carboxylic acid ligands and their chemical formula respectively are \([\text{Zn}_4(\mu_3-O)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,3-\text{HBDC} = 1,2-benzencarboxylic acid}\) and \([\text{Zn}_4(\mu_3-O)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,2-\text{BDC}\). The research of single crystal diffraction of X-ray exhibits that the pentanuclear SBUs of the complex \(\text{Zn}_4\) possesses the topological network similar to the pentanuclear SBUs of \([\text{Zn}_4(\mu_3-O)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,2-\text{BDC}\) and \(\text{Zn}_5\) reveals a three-dimensional 8-linked \(\text{sqc3}\) skeleton based on the SBU of \([\text{Zn}_4(\mu_3-O)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,3-\text{HBDC}\) with chair-shape, and the Schlafli symbol is \([4^{4+}6^6]\). After serious of biological experiments, the application values of the synthesized two compounds were evaluated. Furthermore, their detailed mechanism was also investigated at the same time. The Enzyme-linked immunosorbent assay results present that in comparison with the compound 2, the compound 1 exhibits much stronger inhibitory influences against the inflammatory cytokines releasing. Moreover, the real time Reverse Transcription-Polymerase Chain Reaction displayed that the 1 evidently suppresses the survival gene expression of Porphyria gingivalis, but the compound 2 revealed no effect.

2 Experimental

2.1 Chemicals and measurements

The reagents and chemicals utilized for synthesizing the two CPs could be gained from market, which could be utilized with no extra purification. For the IR spectra (between 4000 cm\(^{-1}\) and 400 cm\(^{-1}\)), we generally record it via applying the spectrometer of Nexus 870 FTIR, and the IR spectra. By utilizing the Elemental analyzer of Perkin-Elmer 240, we analyzed the elements. For the two compounds’ phase purity, they were verified if the PXRD, through utilizing the diffractometer of Bruker D8-ADVANCE (under Cu-K\(\alpha\) radiation with the \(\lambda\) of 0.71073 \(\AA\)) at 10\(\^\circ\) C min\(^{-1}\) scan speed. For the determinations of thermogravimetry (TGA), we can conduct that through utilizing the equipment of Mettler Toledo TGA/SDTAS51 in air with 10\(\^\circ\) C \(\cdot\) min\(^{-1}\) heating rate.

2.2 Preparation and characterization for \([\text{Zn}_4(L)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,3-\text{HBDC}\) and \([\text{Zn}_5(L)\cdot(\mu_3-O)\cdot(\mu_2-COO^-)\cdot\text{ClO}_4^-\cdot3\text{H}_2\text{O}]\cdot2\cdot1,2-\text{BDC}\)

Firstly, the mixture of 0.3 mmol and 60 mg Zn(NO\(_3\))\(_2\)·6H\(_2\)O, 0.2 mmol and 32.2 mg 1,2-HBDC, and 0.05 mmol and 10.6 mg L, 0.2 mmol and 8 mg NaOH as well as 8 mL of the H\(_2\)O was stored into a stainless steel container lined with the Teflon, and the container was heated for four-eight hours to 140\(\^\circ\) C, afterwards, this mixture was cooled slowly at 5\(\^\circ\) C \(\cdot\) h\(^{-1}\) cooling rate to the ambient temperature. The value of pH for this above mixture after and before reaction was about 8. After completing all the above steps, we can gain the complex 1’s colorless-chip crystals with 42\% yield according to the L ligand. Anal. calcd (\%) for the \(\text{Cu}_6\text{H}_2\text{N}_6\text{O}_6\text{Zn}_4\): N, 6.83; H, 2.13; and C, 41.03; found: N, 6.78; H, 2.03; and C, 41.22\%.

Afterwards, 0.2 mmol and 75 mg Zn(ClO\(_4\))\(_2\)·6H\(_2\)O, 0.1 mmol and 16.6 mg 1,3-HBDC, and 0.1 mmol and 21.2 mg L, 0.4 mmol and 16 mg NaOH as well as 8 mL of the H\(_2\)O was stored into a stainless steel container lined with the Teflon and then heated it for two days to 140\(\^\circ\) C, afterwards, this mixture was cooled slowly to the ambient temperature with 5\(\^\circ\) C \(\cdot\) h\(^{-1}\) cooling rate. The value of pH for this above mixture after and before reaction was approximately 9.

After completing all the above steps, we can gain the complex 2’s colorless crystals with block-shape at 42\% yield according to the L ligand. Anal. calcd (\%) for the \(\text{Cu}_6\text{H}_2\text{N}_6\text{O}_6\text{ClZn}_4\): N, 13.57; H, 3.03; and C, 34.90; found: N, 13.86; H, 2.92; and C, 35.12.

The diffractometer of SuperNova was applied to acquire the data of X-ray. The analysis of strength data was conducted with the software of CrysAlisPro and then it can be converted to the files of HKL. The original structural patterns were established via the direct method based program of SHELXS, and the least-squares means based program of SHELXL-2014 was modified. With the overall non-H atoms, the anisotropic parameters could be mixed. Later, the overall hydrogen atoms were fixed on carbon atoms geometrically that they are connected to via applying the commands of AFIX. The two complexes’ parameters of crystallography and their refinement details were summed up in the Table 1 in detail.

2.3 Inflammatory cytokines measurement

The Enzyme-linked immunosorbent assay detection kit was implemented in our current investigation for the measurement of the TNF-\(\alpha\) and IL-1\(\beta\) released into the gingival crevicular fluid after indicated treatment. This conduction was implemented based on the instruction manual, which has been slightly modified. Before the treatment, the chronic periodontitis animal model was constructed. In a word, all the dogs utilized in our present investigation were obtained from Tianjin University (Tianjin, China). This experiment was approved by the Animal Ethics Committee of Tianjin University (Tianjin, China). The chronic periodontitis animal model was induced by removing the bone and wire ligation, detailly the dogs were injected intraperitoneally with 0.3% pentobarbital sodium injection, and the oral cavity was fully exposed after anesthesia. 1.0 mousse thread was used to ligate the roots of the bilateral maxillary second molars. Next, an inoculating loop was used to seed the bacterial suspension on the silk thread and the gingival sulcus. Then the two compounds were given for the treatment at 5 mg/kg concentration. Finally, the
content of the TNF-α and IL-1β released in the fluid of gingival crevicular was detected through the Enzyme-linked immunosorbent assay detection kit (Abcam).

2.4 Porphyria gingivalis survival gene expression

The inhibitory activity of the two compounds against the Porphyria gingivalis relative expression levels was further determined via the real time Reverse Transcription-Polymerase Chain Reaction. This current conduction was accomplished based on the instruction manual, which has been lightly modified. In short, the Porphyria gingivalis bacterial cells were cultured in TSB bacterial culture medium, then the Porphyria gingivalis cells in the logical growth phage were collected and then inoculated them into the 6 well plates at the final destiny of 10⁵ cells per well, followed by the compound addition at a 5 mg/mL concentration. The plates were placed in an incubator at the condition of 37°C for 24 hour. Next, we harvested Porphyria gingivalis, afterwards, we extracted overall RNA in bacteria, then we reverse transcribed the overall RNA into the cDNA after concentration determination. In the end the measurements of the rpoD and rpoA relative expression levels were implemented via the real time Reverse Transcription-Polymerase Chain Reaction, and the 16s utilizes as an internal control gene (Table 2). This experiment was conducted for more than three times, and the acquired results needed to be expressed as mean ± standard deviation.

2.5 Statistical Analysis

All the experiments performed in this present research was repeated at least three times, and the data in this research were expressed as mean ± standard deviation (SD). SPSS 22.0 software and Prism Software were recommend.

### Table 1

The two complexes’ parameters of crystallography and their refinement details.

| Identification code | 1                 | 2                 |
|---------------------|-------------------|-------------------|
| Empirical formula   | C₄₂H₂₂N₆O₁₈Zn₅   | C₃₆H₂₈ClN₁₂O₁₆Zn₄ |
| Formula weight      | 1229.54           | 1181.63           |
| Temperature/K       | 273.15            | 293.15            |
| Crystal system      | triclinic         | monoclinic        |
| Space group         | P-1               | C2/c              |
| a/Å                 | 7.3429(12)        | 29.7423(12)       |
| b/Å                 | 11.0631(13)       | 7.8659(2)         |
| c/Å                 | 13.1823(9)        | 21.6632(5)        |
| α°                  | 110.765(2)        | 90                |
| β°                  | 95.463(2)         | 117.3580(10)      |
| γ°                  | 104.2740(10)      | 90                |
| Volume/Å³           | 950.5(2)          | 4501.2(2)         |
| Z                   | 1                 | 4                 |
| ρcalcg/cm³          | 2.148             | 1.744             |
| μ/mm⁻³              | 3.209             | 2.249             |
| Data/restraints/parameters | 3611/25/343 | 4083/56/337 |
| Goodness-of-fit on F² | 1.071             | 1.070             |
| Final R indexes [I>=2σ (I)] | R₁ = 0.0440, ωR₁ = 0.1013 | R₁ = 0.0382, ωR₁ = 0.1035 |
| Final R indexes [all data] | R₁ = 0.0585, ωR₁ = 0.1092 | R₁ = 0.0455, ωR₁ = 0.1084 |
| Largest diff. peak/hole / e Å⁻³ | 0.63/-0.73 | 1.31/-0.75 |
| CCDC                | 2033746           | 2033747           |

### Table 2

Sequences of the primers used in this study.

| Genes | Sequences                  |
|-------|----------------------------|
| rpoD  | GAAATGAATGGGCAGCGCCGTT     |
| rpoA  | GGGCAGCGGTAGGAGAAA         |
| 16s   | AATGGGCAGCGGTAGGAAA        |
|       | ATCACCGGGAGGAGGAAATCG      |
|       | AGTTAAAGCGAGCCCCGTTGTA     |
|       | GCGCCCAATCGCAAAATC         |
ed for statistical analysis. One-way ANOVA was used for the statistical analysis among multiple groups. \( P < 0.05 \) was considered as significant different.

### 3 Results and Discussion

#### 3.1 Crystal structures

The crystallographic study of X-ray exhibits that the complex 1 was crystallized in a triclinic \( P\text{-}1 \) space group, which indicates a two-dimensional skeleton according to the pentanuclear structure unit. For the complex 1, this pentanuclear structure unit is composed of a ligand of L, five Zn(II) ions (i.e., two Zn1 ions, a Zn2 ion and two Zn3 ions), a pair of \( \mu_7\text{-OH} \) groups as well as four 1,2-BDC\(^{2−} \) ions. The center of Zn1 is surrounded through four oxygen atoms of carboxyl (i.e. O8, O7, O3 and O2) in three 1,2-BDC\(^{2−} \) ions, a nitrogen atom (i.e. N1) in a ligand of L as well as an oxygen atom (i.e. O9) originated from an \( \mu_7\text{-OH} \) ion, generating \([\text{ZnNO}_5]^{-}\), a distorted geometry of octahedron (Fig. 1a). The Zn2 ion is situated in the center of regular octahedron \([\text{ZnO}_6]^{-}\), and it is hexacoordinated, which is accomplished via 4 carboxyl oxygen atoms (i.e. O9\(^{2−}\), O3, O8\(^{2−}\) and O8) in 4 1,2-BDC\(^{2−} \) ions along with two oxygen atoms (i.e. O9\(^{2−}\) and the O9) in the 2 \( \mu_7\text{-OH} \) ions. The pentacoordinated center of Zn3 is a distorted trigonal biconical geometry of \([\text{ZnO}_5]^{-}\), which is filled with an oxygen atom (i.e. O9) originated from an \( \mu_7\text{-OH} \) ion and 4 carboxyl oxygen atoms (i.e. O7, O6, O4 and O1) in 4 1,2-BDC\(^{2−} \) ions. Moreover, five Zn(II) ions are connected through 6 \( \mu_7\text{-COO}^{−} \) ions and two groups of \( \mu_7\text{-OH}^{−} \) to generate \([\text{Zn}_5(\mu_7\text{-OH})_2(\mu_7\text{-COO}^{−})_6]^{2+}\), a pentanuclear structure unit. For the Zn1\(\cdots\)Zn3, Zn2\(\cdots\)Zn3 and the Zn1\(\cdots\)Zn2, the intermetallic distances generated through the groups of \( \mu_7\text{-OH} \) are 3.0034(8) \( \text{Å} \), 3.5026(7) \( \text{Å} \) and 2.8793(6) \( \text{Å} \). Besides, it should be noted that the ligand of L is located near one inversion center, while the Zn2 is located at another. The lengths of Zn-O are between 1.916 (3) \( \text{Å} \) and 2.285 (3) \( \text{Å} \), while the distance of Zn-N is 1.940 (3) \( \text{Å} \). The pentanuclear structure units of \([\text{Zn}_5(\mu_7\text{-OH})_2(\mu_7\text{-COO}^{−})_6]^{2+}\) in the compound 1 are interconnected through the 1,2-BDC\(^{2−} \) ions, this producing the one-dimensional chains (Fig. 1b), and such 1D chains are in-depth bridged through the ligands of L to produce a two-dimensional network (Fig. 1c). At the aim of better understanding the complex 1’s structure, the software of TOPOS was utilized for the analysis of the topology of two-dimensional skeleton. In topology, the 1,2-BDC\(^{2−} \) ions and the ligands of L can be viewed as the 2-linked connectors, and the SBUs of \([\text{Zn}_5(\mu_7\text{-OH})_2(\mu_7\text{-COO}^{−})_6]^{2+}\) can be regarded as the 4-linked nodes. Therefore, a similar two-dimensional 4-linked \([4^1\cdot 6^3]\) topological network of \textit{sqf} \(\text{I}^{2-}\) was acquired (Fig. 1d).

The complex 2 possesses a tetranuclear unit based three-dimensional skeleton, which is part of the monoclinic space group of \( \text{C2/c} \). The complex 2’s structure unit contains a 1,3-HBDC\(^− \) ion, two ligands of L, 4 Zn(II) ions (i.e. two Zn1 ions and two Zn2 ions), 4 \( \mu_7\text{-OH}^{−} \) ions, a 1,3-BDC\(^{2−} \) ion, three lattice molecules of water as well as a ClO\(_4^{-}\) ion. It should be noted that the chlorine atom Cl1 of perchlorate is located on the biaxial axis. As indicated in the Fig. 2a, Zn1 is pentacoordinated, which is completed via two

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Fig. 1  (a) The asymmetry unit view for complex 1. (b) The one-dimensional chain for complex 1. (c) The complex 1’s two-dimensional skeleton. (d) 4-linked network of the complex 1.
The SBUs of the basis of the structural characteristics of the complex better, we needed to conduct the topological analysis. On the aim of understanding the three-dimensional skeleton of the complex, four Zn ions are linked through four groups of \( \mu_3 \text{-OH} \) and the complex \( \text{Zn} \)–\( \text{O} \)–\( \text{Zn} \) is 98.76 \( \text{Å} \), 30285 \( \text{Å} \), and 60833 \( \text{Å} \). The angle of \( \text{Zn}–\text{O}–\text{Zn} \) is 98.76 \( \text{Å} \) for the Zn2–O1–Zn2 and 90.26 \( \text{Å} \) for the Zn1–O3–Zn2, and 90.75 \( \text{Å} \) for the Zn1–O4–Zn2, respectively. The length of Zn–O bond is between 1.928 \( \text{Å} \) and 2.310 \( \text{Å} \) and the length of Zn–N bond varied from 1.970 \( \text{Å} \) to 1.981 \( \text{Å} \). The Zn2 ion and Zn1 ion are inter-connected via the ions of 1,3-BDC\(^{2-}\) and 1,3-HBDC\(^{-}\) to form the two-dimensional layers (Fig. 2b), and these two-dimensional layers are in-depth linked via the ligands of L to produce a three-dimensional skeleton (Fig. 2c). At the aim of understanding the three-dimensional skeleton better, we needed to conduct the topological analysis. On the basis of the structural characteristics of the complex 2, the SBUs of [Zn\(_3\)(\( \mu_4 \text{-OH} \))\(_4\)]\(^{4+}\) can be considered as 8-linked nodes, and the L ligands, 1,3-BDC\(^{2-}\) and 1,3-HBDC\(^{-}\) ion can be decreased to the 2-linked spacers. Therefore, the complex 3 can be classified as the 8-linked network, which possesses a \([4^2 \times 6^2]\) Schlafli symbol (Fig. 2d).

At the aim of detecting the products’ phase purity, the experiments for the PXRD were implemented for these two compounds (Figs. 3a and 3b). The peak positions of PXRD diagrams of the simulation and experiment are in line with each other, this reflects that for the products of crystal with bulk-shape, crystal architectures are a real representative. The differences for the strength can attribute to the preference. In order to in-depth estimate the two compounds’ stabilities, the thermal behavior of the complex 1 and the complex 2 was investigated via the TGA between 25°C and 800°C at 10°C·min\(^{-1}\) heating rate in argon, as exhibited in the Fig. 3c. The complex 1 possesses high thermal stability when the temperature is less than 220°C. When the temperature increased, the products would lose their primary ligands (a ligand of L) and auxiliary ligand (a pair of \( \mu_3 \text{-OH} \) groups and four 1,2-BDC\(^{2-}\) ions) gradually with the increase of temperature. For the complex 2, the weightlessness of 12.10% (calculated as 11.93%) at 25 to 249°C temperature may be due to the removal of three lattice molecules of water and an uncoordinated \( \text{ClO}_4^{-}\) ion; the second weightlessness equivalents to the organic ligands release at approximately 250°C. Considering the following bioactivity test, it is necessary to downsize the crystals of 1 and 2 in nanoscale, which facilitates the release of drugs to the whole body and absorbed by the specific tissues by intravenous administration and pass through the blood-brain barrier. With this in mind, the grinding and ultrasonic treatment methods were applied to

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Fig. 2 (a) The asymmetry unit view for complex 2. (b) The complex 2’s two-dimensional layered network. (c) The complex 2’s three-dimensional pillar-layered skeleton. (d) The 8-linked network of the complex 2.
downsize the crystals of 1 and 2. The single crystals of 1 and 2 were subjected to a mechanical grinding in a mortar and pestle for about 30 min, which were following by ultrasonic treatment in DMSO at 70 W for 6 h. The formation of the nanostructures has been further confirmed by scanning electron microscopy (SEM) studies that are obtained by drop-casting a DMSO-dispersed solution of the particles on a glass surface. Complex 1 and 2 adopt almost spherical morphologies in order to minimize the interfacial free energy between the particle and the solvent molecules.

The results show that the hydrodynamic diameter for complexes 1 and 2 is around 350 nm and 200 nm, respectively (Fig. S1).

3.2 Compound reduced the releasing of the inflammatory cytokines

After the synthesis of the two compounds, their application values on the chronic periodontitis was firstly assessed via detecting the content of the inflammatory cytokines, such as TNF-α and IL-1β in the fluid of gingival crevicular.

Fig. 3  The diagram of PXRD for the complex 1 (a) and the complex 2 (b). (c) The curve of TGA curve for the complex 2.

Fig. 4  Reduced the inflammatory cytokines releasing levels after treated via the compound. The animal model of chronic periodontitis was built and the two compounds were injected to implement the treatment at 5 mg/kg concentration. The TNF-α and IL-1β content in the fluid of gingival crevicular was detected through the Enzyme-linked immunosorbent assay detection kit.

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As the results showed in the Fig. 4, we can gain that in comparison with control group, the TNF-α level and IL-1β level were obviously increased in the fluid of gingival crevicular in model group. However, after treated with the compound 1, the inflammatory cytokines content was evidently inhibited, whereas the compound 2 only showed a little influence on the inflammatory cytokines releasing.

3.3 Compound inhibited the relative expression of the *Porphyria gingivalis* survival gene

In our above investigation, we have proved that the compound 1 exhibits superb inhibitory activity against the content of the TNF-α and IL-1β released into the fluid of gingival crevicular. Nevertheless, the suppression activity of the two compounds against the *Porphyria gingivalis* survival gene relative expression levels was still need to be investigated. Therefore, the real time Reverse Transcription-Polymerase Chain Reaction was implemented for determination. The results in the Fig. 5 indicates that the compound 1 reveals much more superb inhibitory activity than the compound 2 against the *Porphyria gingivalis* survival gene expression.

4 Conclusion

In conclusion, we have synthesized two novel coordination polymers involving Zn(II) via the mixed-ligand method and characterized them in structure by the analysis of single-crystal X-ray diffraction and the element. The research of single crystal diffraction of X-ray displays that the complex 1 possesses the topological network similar to the pentanuclear SBUs of $[\text{Zn}_5(\mu_3-OH)_4(\mu_2-COO^-)_6]^{2+}$ and the complex 2 reveals a three-dimensional 8-linked $\text{sqc}_3$ skeleton based on the SBU of $[\text{Zn}_4(\mu_2-OH)_4]^{4+}$ with chair-shape, and the Schläfli symbol is $4^{21}6^4$. The ELISA results exhibited that the compound 1 could evidently suppresses on the releasing of the inflammatory cytokines, but the compound 2 had no effect. Besides, in comparison with the compound 2, the compound 1 possessed a much stronger inhibitory effect against the *Porphyria gingivalis* survival gene expression. To sum up, compound 1 was more excellent than compound 2 to be a candidate for the chronic periodontitis treatment.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Data Availability

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

Acknowledgments

Not applicable.

Supporting Information

This material is available free of charge via the Internet at http://dx.doi.org/jos.70.10.5650/jos.ess20269
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