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# A BIBLIOMETRIC ANALYSIS OF NANOCRYSTALLINE CELLULOSE RESEARCH AS MEDICAL IMPLANT USING VOSVIEWER

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## ABSTRACT

**Background:** Nanocrystalline cellulose has great promised potential for biomedical applications due to its abundant material availability, biodegradability, biocompatibility, and low weight. Research on nanocrystalline cellulose as medical implants has rarely been studied in the past 10 years, although this material has tremendous potential such as bone implants and cardiovascular implants. **Objective:** This study has the aim to analyzing development of related research on nanocrystalline cellulose as medical implants using a bibliometric approach using computationally analyzed using VOSviewer. **Methods:** The article data we have obtained using the Publish or Perish software by retrieving the database from Google Scholar. The keyword "nanocrystalline cellulose, medical implants, biomedical" is used with the publication time span from 2012 to 2022. Data processing uses Microsoft Excel. Computational mapping using VOSviewer. **Results:** Research on the application of nanocrystalline cellulose has been carried out several times, this can be proven from computational mapping analysis using VOSviewer which shows the term "nanocrystalline cellulose" is in the same cluster as the term "medical implant". However, research on the application of nanocrystalline cellulose as medical implants is still rarely carried out, this is evidenced by the small frequency indicated by the two terms. **Conclusion:** Based on the results of mapping the collected article data, research on the application of nanocrystalline cellulose as medical implants is an interesting topic. However, this topic is still rarely studied. Therefore, this review can be a starting point for selecting the topic of research on the application of nanocrystalline cellulose materials as medical implants as a consideration for determining the research theme to be taken.

***Keywords*****:** *Bibliometrics, Computational analysis, Nanocrystalline cellulose, Medical implants, VOSviewer*

## INTRODUCTION

Cellulose is a polymer consisting of carbohydrate monomers. The carbohydrate monomer of cellulose is β-D glucopyranose. High functionality can be found in cellulose because cellulose consists of three hydroxy groups per anhydro glucose. Cellulose is a non-toxic, easily biodegradable, renewable material, and is abundant in nature. For more than 150 years, cellulose has been studied for a wide range of uses, including the production of paper, foodstuffs, biomaterials, and medical.[1]

Nanocrystalline cellulose is a pure crystalline cellulose derivative that has rod-shaped particles, 20-30 nm in diameter and 160-400 nm in length, has a relatively low aspect ratio[2,3]. Nanocrystalline cellulose is a nanofibril element from crystalline cellulose obtained after removing the amorphous part by hydrolysis reaction with strong acids and the particle size depends on temperature, acid concentration, and hydrolysis time[4]. Nanocrystalline cellulose has been tested for various applications, one of which is reinforcement for the biocomposite, antimicrobial, and medical device industries as well as green catalysts[5].

Several studies on biomedical applications, especially medical implants that use cellulose, include the effect of adding nanocellulose to the compressive strength of bone cement[6], nanocrystal cellulose for bone tissue regeneration[7], nanocrystal cellulose reinforced with fibrin nanocomposites for vascular replacement applications[8]. The bibliometric research on the application of nanocrystalline cellulose, among others, a study of nanocrystalline cellulose's potential as a drug delivery system[9], analysis of the synthesis of nanocrystalline cellulose for packaging[10].

Research on computational mapping of bibliometric analysis of data, nevertheless, that has been presented in the area of application of nanocrystalline cellulose as medical implants specifically have not been carried out. In particular Bibliometric study of research published from 2012 to 2022 during the previous ten years using VOSviewer.

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Therefore, this study was conducted for analyzing nanocrystalline cellulose using bibliometrics materials as medical implants. This study aims to aid researchers in planning and selecting research subjects. In particular, the topic of application of nanocrystalline cellulose materials for medical implants is a consideration for determining the research theme to be taken.

## METHOD

The data for the articles used in this study were taken from publications by Google Scholar's index. Google Scholar was used in this investigation because the Google Scholar database is open source. Used reference manager software Publish or perish to conduct a literature review on the topic of the author's choice. Detailed information about the use of software and the process of obtaining data, we obtained from research conducted by Husaeni and Nandiyanto[11].

The research was conducted through several stages:

1. Gathering information on publications using the Publish or Perish program,
2. bibliometric data processing using Microsoft Excel software,
3. bibliometric data computational mapping analysis utilizing VOSviewer program,
4. analysis of computational mapping results.

Search article data in Publish or Perish software using the keywords "nanocrystalline cellulose, medical implants, biomedical". Articles published in the period 2012-2022. Articles that have been collected by the Publish or Perish software are exported into research information system (.ris) files and comma evaluate format (*.csv). The comma evaluate format (*.csv) data is processed in Microsoft Excel by separating articles based on the year of publication and the number of publications. Research information system (.ris) data is used for mapping using VOSviewer by visualizing and evaluating trends using bibliometric maps. Utilizing the network (co-citation) connecting existing items, VOSviewer generates three different types of mapping publications: network visualization, overlay visualization, and density visualization.

## RESULT

### Publication data search results

One thousand data articles that fit the research criteria were found by data searching in the Publish or Perish application reference manager's Google Scholar database. The information gathered in the form of article metadata, which includes the name, title, year, journal name, publisher, quantity of citations, article links, and associated URLs. In the VOSviewer examination of this study, several samples of published data are shown in Table 1. The top 10 publications with the most citations were selected as data samples. The total number of citations from all publications utilized in this study is 49774; the total number of citations annually is 4977.40; the average number of authors in the articles used is 4.03; the average h-index across all articles is 103; and the average g-index is 188.

**Table 1.** Publication data of nanocrystalline cellulose as medical implants

| Authors | Title | Year | Cites |
|---|---|---|---|
| Patra et al [12]. | Nano based drug delivery systems: recent developments and future prospects | 2018 | 2606 |
| Croisier and Jérôme [13]. | Chitosan-based biomaterials for tissue engineering | 2013 | 1947 |
| Lin and Dufresne [14]. | Nanocellulose in biomedicine: Current status and future prospect | 2014 | 1330 |
| Oryan et al [15]. | Bone regenerative medicine: classic options, novel strategies, and future directions | 2014 | 966 |
| Lee and Jun [16]. | Silver nanoparticles: synthesis and application for nanomedicine | 2019 | 750 |
| Ali and Ahmed [17]. | A review on chitosan and its nanocomposites in drug delivery | 2018 | 677 |
| Boateng and Catanzano [18]. | Advanced therapeutic dressings for effective wound healing—a review | 2015 | 637 |
| Komi and Hamblin [19]. | Chitin and chitosan: production and application of versatile biomedical nanomaterials | 2016 | 636 |
| Jorfi and Foster [20]. | Recent advances in nanocellulose for biomedical applications | 2015 | 613 |
| Lee et al [21]. | Conversion of lignocellulosic biomass to nanocellulose: structure and chemical process | 2014 | 601 |

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**Research development of nanocrystalline cellulose as medical implant**

Figure 1 shows the development of research on nanocrystalline cellulose as medical or biomedical implants over the last 10 years. In the range of 2012 to 2021, it has increased. Meanwhile, in 2022, it has decrease.

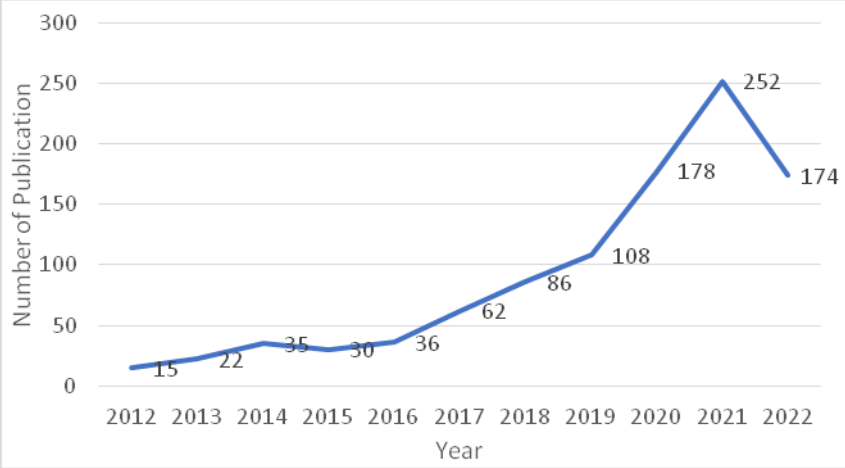


**Figure 1.** Graph of research progress of nanocrystalline cellulose as a medical implant

**Visualization of nanocrystalline cellulose topic areas as medical implants using VOSviewer**

Computational mapping was performed on article data obtained from the Publish or Perish reference manager software. For computational mapping used VOSviewer software. 254 objects were discovered from the computational mapping findings. Cluster classification shows how closely related each term is. Each item found related to nanocrystalline cellulose as a medical or biomedical implant is divided into 10 clusters, namely:

(i) Cluster 1 contains 41 items marked in red, these 41 items are addition, additive manufacturing, advance, advantage, basis, biomedical engineering, biopolymer, carboxymethyl cellulose, chitin, chitosan, collagen, composite material, derivative, drug, example, instance, interest, lignin, medical application, mouse, nanomaterial, nanomedicine, overview, potential, potential application, processing, research, silver nanoparticle, starch, state, surgical implant, technology, tissue engineering application, treatment, trend, tumor, use, variety, vitro, vivo, year.

(ii) Cluster 2 contains 39 items marked in green, these 39 items are ability agent, antimicrobial agent, application, artificial implant bacterium, biofilm, biomedical field, biomedical implant, biomedicine, biotechnology, body, chitin nanocrystal, cytotoxicity, delivery, device, drug delivery system, electronic, environment, film, infection, light, medical device, nanocrystal, nanoparticle, pcl, polymer, recent advancement, recent trend, researcher, role, sensor, shape memory polymer, silver, surgery, synthesis, system, textile, wound dressing.

(iii) Cluster 3 contains 37 items marked in blue, the 37 items are advanced application, aerogel, antibacterial property, bacterial cellulose, bacterial nanocellulose, bio, biodegradable polymer, biomaterial, biomedical research, bnc, cartilage, cartilage implant, cellulose nanofibril, chemical, cnf, composite, cosmetic, dental implant, dressing, electronic device, engineering, food, food packaging, formation, human body, isolation, medical field, nanocellulose fiber, novel material, paper, potential biomedical

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application, product, pva, structure, time, vascular implant, water.

(iv) Cluster 4 contains 36 items marked in yellow, the 36 items are biocomposite, biomedical application, biomedical area, biomedical industry, biosensor, cellulose, challenge, cnc, comprehensive review, current status, drug delivery, fabrication, fiber, filler, future prospect, medical implant, nanocellulose, nanocrystalline cellulose, natural polymer, ncc, nfc, perspective, pla, plant, polyhydroxyalkanoate, potential use, production, recent advance, recent development, review, rod, technique, unique property, wound healing.

(v) Cluster 5 contains 25 items marked in purple, these 25 items are alloy, antibacterial activity, biocompatibility, bone, bone implant, bone tissue engineering, coating, cross, effect, implant, implant material incorporation, integration, kind, mechanical property orthopedic implant, packaging, preparation, property, recent year, surface, surface modification, titanium, type, work.

(vi) Cluster 6 contains 25 items marked in sky blue, these 25 items are attention, biomedical device, biomedical material, biomedical use, case, cell, cellulose nanofiber, evaluation, figure, graphene, hand, hydrogel, immobilization, implantation, implantation site, interaction, matrix, number, regeneration, scaffold, silk fibroin, study, tissue, week.

(vii) Cluster 7 contains 19 items marked in orange, the 19 items are 3d bioprinting, advance, approach, area, biomedical purpose, biomedical science, bioprinting, development, form, healing, medicine,modification nanotechnology, opportunity, patient, recent progress, regenerative medicine, tissue engineering, tissue regeneration.

(viii) Cluster 8 contains 18 items marked in brown, the 18 items are bone regeneration, bone tissue, caprolactone, cartilage tissue engineering, characterization, energy, extraction, field, gelatin, morphology, poly, prospect, reinforcement, sample, silk, solution, utilization, wide range.

(ix) Cluster 9 contains 14 items marked in pink, the 14 items are 3d printing, biological property, biomedical application, blood, cellulose nanocrystal, increase, nanocomposite, nanofiber, performance, polysaccharide, presence, progress, prosthesis, tissue engineering scaffold.

(x) Cluster 10 contains 1 item marked with dusty pink color, the 1 item is pharmaceutical application.

Three pieces make up the mapping visualization in this study, namely network visualization (see Figure 2(a)), overlay visualization (see Figure 2(b)), and density visualization (see Figure 2(c))[24].

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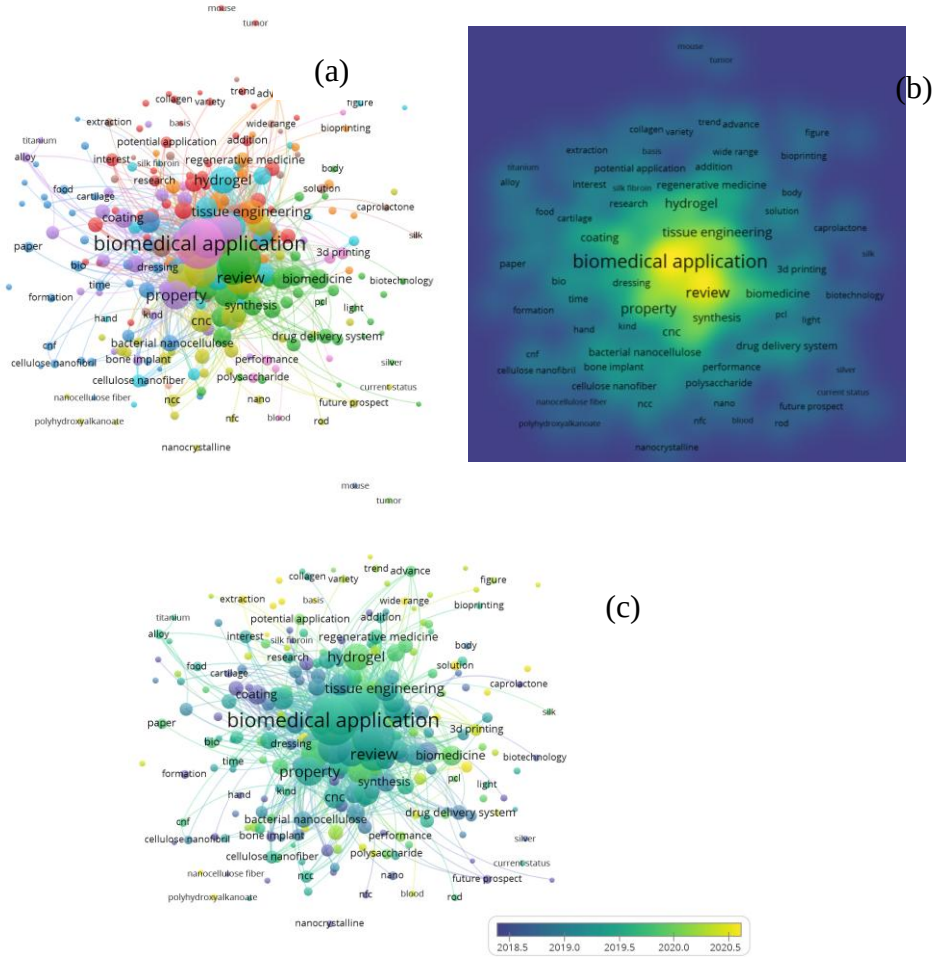


**Figure 2.** Network visualization (a), overlay visualization (b), density visualization (c)

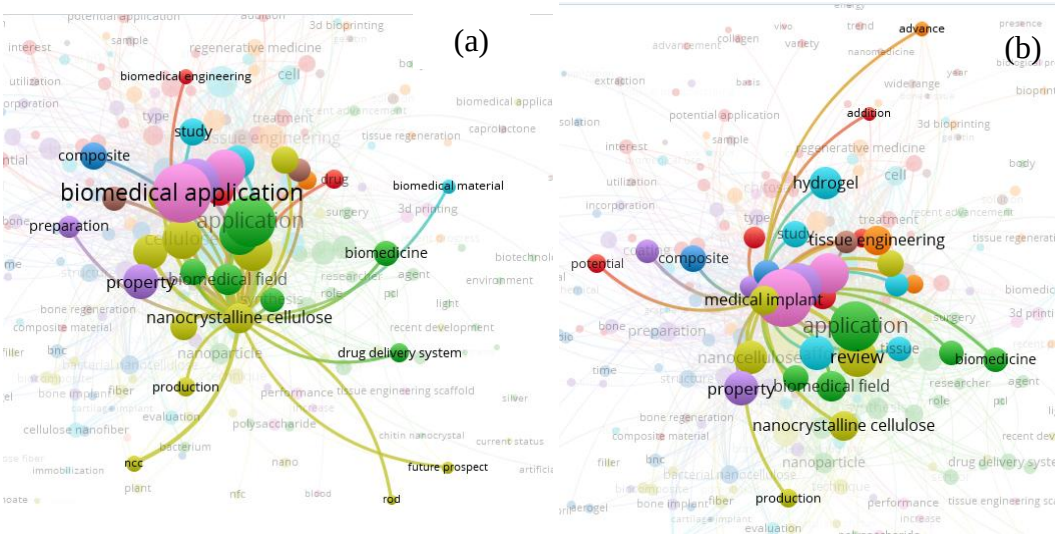


**Figure 3.** Network visualization term nanocrystalline cellulose (a), network visualization term medical implant (b)

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Figure 3(a) shows the linkage network of nanocrystalline cellulose with other terms, namely rod, future propect, ncc, production, drug delivery system, production, synthesis, biomedicine, property, preparation, cellulose, application, biomedical material, drug, biomedical application, composite, study, biomedical engineering. Figure 3(b) shows a network of medical implant relationships with other terms, namely production, nanocrystalline cellulose, property, biomedical field, biomedicine, review, scaffold, nanocellulose, tissue, application, potential, coating, composite, type, study, tissue engineering, hydrogel, addition, advance.

## DISCUSSION

Nanocrystalline cellulose as a material that has the potential to be applied in a variety of ways must of course go through in-depth research. Nanocrystalline cellulose can be used as medical implants, drug delivery system, wound healing, tissue engineering, cardiovascular disease, and antibacterial/antimicrobial activities[27]. Research on the application of nanocrystalline cellulose has been carried out several times, this can be proven from computational mapping analysis using VOSviewer which shows the term "nanocrystalline cellulose" is in the same cluster as the term "medical implant" in cluster 4. Each existing cluster's representation of the link between a term and another[22], which means that the two terms are closely related. However, research on the application of nanocrystalline cellulose as medical implants is still rarely done. This is evidenced by the small circle indicated by the two terms. The size of the circle for each term varies according to how frequently the term occurs[22]. The label circle's size shows a positive correlation with the terms that appear in the abstract and title[23]. The more often the term is found, the larger the label size[11].

Figure 2(a) shows the respective clusters of frequently researched terms related to the topic of nanocrystalline cellulose as medical or biomedical implants. Figure 2(b) shows the overlay visualization in the study of nanocrystalline cellulose. The uniqueness of the research on associated terms is displayed in this visualization overlay[22,23,25,26]. The time of popularity of the term nanocrystalline cellulose as medical or biomedical implants in popular research is in 2018 to 2020. Thus, we can easily make new research on medical or biomedical nanocrystalline cellulose implants. Figure 2(c) shows the density visualization. Density visualization means that the brighter the yellow color and the larger the circle diameter of the term label, the more often the term appears[11,22,23,24]. This indicates that much study has been conducted on linked terms. On the other hand, if the color of the term fades close to the background color, then there haven't been many research done on the subject. Based on Figure 2(c) biomedical application is the term that appears most often, while nanocrystalline cellulose and medical implant are related terms but rarely appear. Therefore, research on the application of nanocrystalline cellulose as a medical implant has a great opportunity to continue.

Research that has discussed the use of nanocrystalline cellulose, including the use of nanocrystalline cellulose for cardiovascular implants because of its strength, makes this material a reinforcing material for biocompatible matrices such as fibrin are used to produce new types of biomaterials to replace small diameter blood vessels[28]. Nanocellulose's porous, permeable nature can provide a friendly environment for colonize cells, thereby supporting the growth of new tissues. Therefore, nanocrystalline cellulose particles have great potential to be utilized in the biomedical sector, especially bone implants, wound healing, cartilage, and artificial liver regeneration[27].

Based on the results of mapping the collected article data, the keywords may be observed. nanocrystalline cellulose and its association with medical implants are still rarely used in research. Although there have been many studies of nanocrystalline cellulose in other biomedical applications. Therefore, this research topic will be an interesting topic to study.

## CONCLUSION

The purpose of this study is to examine the growth of research on nanocrystalline cellulose as medical implants using a bibliometric approach with computational analysis using VOSviewer. Of the 1000 articles collected from data acquisition using Publish or Perish which was then mapped using VOSviewer showing research on the application of nanocrystalline cellulose has been carried out several times this can be proven from computational

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mapping analysis using VOSviewer which shows the term "nanocrystalline cellulose" is in the same cluster with the term "medical implant". However, research on the application of nanocrystalline cellulose as medical implants is still rarely done, this is evidenced by the small frequency indicated by the two terms. Based on the mapping results, research on the application of nanocrystalline cellulose as a medical implant is an interesting topic. However, this topic is still rarely studied. Therefore, this review can be a starting point for selecting the topic of research on the application of nanocrystalline cellulose materials as medical implants as a consideration for determining the research theme to be taken, because this topic still has a high enough opportunity for research.

## ETHICAL APPROVAL

There is no ethical approval.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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No specific funding was provided for this article.

## AUTHOR CONTRIBUTIONS

Conceptualization, Hafilah D and Nandiyanto AB ; methodology, Hafilah D and Nandiyanto AB; software, Hafilah D; preparation of the original draft, Hafilah D; supervision, Nandiyanto AB.

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