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Effect of Incorporation of Copper Nanoparticles at Varying Percentages into Irreversible Hydrocolloid Impression Material on it's Tear Strength and Flow: A Comparative Study

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Abstract

Aim: Effect of incorporation of copper nanoparticles at varying percentages into irreversible hydrocolloid impression material on its tear strength and flow.

Materials and Methods: A total of 120 samples are fabricated and divided into 4 groups (1 control group and 3 experimental groups) consisting of 30 samples in each group. 30 samples are further divided into 2 subgroups each consisting of 15 samples to evaluate tear strength and flow. Sample preparation for tear strength: Impression material IMPRECEED (GC Corporation Tokyo, Japan) was mixed as recommended by the manufacturer and poured in to a customized mould with a dimensions of [8 X 1 X 0.5] cms. A glass slab is placed on the top of the mould and a standard weight of 1kg was applied on glass slab to ensure a uniform thickness of the specimen. After the material has set, the specimen was removed carefully from the mould. Similarly, samples were prepared for irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.25wt%, 0.5wt%, 1.0wt%. Testing of specimens for tear strength: Strain gauge is used to measure tear strength. Specimen is placed in between the jigs. Load is applied and gradually increased. The load at which the specimen tears was noted from the console of the strain gauge. Measurement of flowability: 0.5 ml of hydrocolloid irreversible impression material IMPRECEED (GC Corporation Tokyo, Japan) is injected onto a glass slab using a 2ml disposable syringe within 60 seconds of mixing as recommended by the manufacturer. Another glass slab was placed on top of the impression material and a standard weight of 1.5kg is placed on the outer surface of the upper glass slab. After the final set, the weight was removed and the perimeter of the impression disc was measured with the help of a matlab software called edge detector. The sample was scanned with the help of a scanner. The scanned impression discs are programmed in the mat software. This program detects the perimeter and diameter of the discs, thus the flowability is evaluated. Similarly, all the 15 samples of each group are tested for flow and recorded.

Results: The comparison of mean tear strength between the Groups A1, B1, C1 and D1 was done using Mann-Witney U test. It was observed that the mean tear strength was higher in control group A1 (241±2.84). The mean tear strength was lower in test specimens of Group B1 (166.7±23.2) followed by Group C1 (94.7±20.6) and Group D1 (64.2±21.6) (p=0.000*). The mean comparison of flowabiltiy between the Groups A2, B2, C2 and D2 was done using kruskal-wallis test. It was observed that the mean flowabilty was significantly higher in Control Group A2 (3.71±0.02). The mean flowability was lower in samples of Group B2 (3.62±0.04) followed by Group C2 (3.52±0.05) and Group D2 (3.39±0.04) (p=0.000*).

Conclusion: The results of the present study concluded that, among the Groups tested (A1, B1, C1, D1), the tear strength of irreversible hydrocolloid impression material decreased progressively in descending order with addition of copper nanoparticles at 0.25 wt%, 0.5 wt% and 1.0 wt% respectively. The test specimens of Group A1 (unmodified) showed the highest values of tear strength in comparison with Group B1, Group C1 and Group D1 (modified). Among the Groups tested (A2, B2, C2, D2), the flowability of irreversible hydrocolloid impression material decreased progressively in descending order with addition of copper nanoparticles at 0.25 wt%, 0.5 wt% and 1.0 wt% respectively. The test specimens of Group A2 (unmodified) showed the highest values in comparison with Group B2, Group C2 and Group D2 (modified).

Keywords: Irreversible Hydrocolloid Impression Material, Copper Nanoparticles, Tear Strength, Flowability, Strain Gauge, Matlab, Edge Detection Software

Introduction

The dental therapeutics at large is associated with significant amount of risk due to exposure to various micro-organisms. There are many infectious diseases that can be transmitted in a clinical practice. Infection control is directed at prevention to exposure of such infections and also to prevent it being transferred from person to person.[1] Of the many potential contamination pathways in dental practice, dental impressions invariably are contaminated with patient's saliva and sometimes blood. Such fluids may contain microorganisms, some of which may have potential for disease transmission and at times with serious outcome.[2] Dental Impression is a negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in diagnosing and treatment of dental anamolies.[3] Various impression materials are available such as dental plaster, reversible hydrocolloid impression material, irreversible hydrocolloid impression material, elastomers etc., among which Irreversible hydrocolloid impression material is most frequently used impression material in prosthodontics. The widespread use of irreversible hydrocolloid impression material, ADA specification no:18 attributed to their hydrophilic, easy to manipulate, good surface detail reproducibility even in the presence of saliva, reasonably accurate and inexpensive.[4] Dental impressions that have been exposed to infected saliva and blood contribute a significant role for cross-contamination. In fact, infectious microorganism from the oral cavity can survive on the impression surface and be transferred to the diagnostic and working casts. Handling of both impressions and casts can potentially transmit infectious diseases to dentist, dental auxiliaries and technicians.[5] Therefore, the American Dental Association (ADA) recommends the dentists and their assistants take necessary precautions to protect patients and themselves from these potentially transmissible contaminants.[6] It is important that dental practitioners follow strict infection protocol in clinical practice. The risk of infections transmitted by saliva, blood and plaque is considered a potential occupational hazard as they contain pathogenic microorganisms and viruses which can transmit diseases from simple to highly virulent such as common cold, pneumonia, tuberculosis, viral hepatitis, herpes, corona virus and human immunodeficiency virus infection and acquired immunodeficiency syndrome.[7] Prosthodontic patients are generally a high-risk group relative to their potential to transmit infectious disease as well as acquire them because geriatric patients are identified as the high-risk group for the development of healthcare-associated infections (HAIs) due to the age-related decline of the immunosenescence. There has been an increased awareness of the need for cross infection control measures and prevent the possible routes of transmission which was frequently ignored in the past.[8] Guidelines have been laid down by the American Dental Association (ADA) towards this goal and the measures to be observed in clinical and laboratory procedures during impression making and pouring of the casts. Due to their hydrophilic nature combined with porous structure permits alginates to inhabit higher loads of microorganisms not only on the surface but also within the material. Hence, surface disinfection of alginate cannot be achieved in toto. On this basis, researches have proposed numerous methods of disinfection protocol for irreversible hydrocolloid impression. Such as immersion and spraying. Disinfection by immersion can be achieved only if the impression is exposed to the disinfectant for 30 minutes or more. It is known that irreversible hydrocolloid impression material undergoes distortion if they are subjected to this routine. Disinfection of the impression by spraying method can result in the loss of surface detail of the dental casts. Hence, these disadvantages demand for other methods of disinfection.[9] An alternative procedure would be the incorporation of a disinfectant directly into an impression material. This will eliminate the need to immerse these accurately made impressions in any disinfectant solution which may lead to dimensional changes. Recently incorporation of a disinfectant material such as copper, silver, zinc oxide, copper oxide, titanium dioxide at a nano scale directly into the impression material are being assessed for their disinfection capabilities.[10] Nanotechnology, a scientific revolution of twenty first century, pertaining to manipulating matter on an atomic scale. Recently nanotechnology has been increasingly used in material science for their enhancement in physical and mechanical properties due to the alteration of filler size which is considered for the performance of the materials.[11] Copper is a transition metal belonging to 3D group of Mendeleev periodic table. The word copper originates from the Latin word "cuprum". It is generally described as ductile, malleable & flexible metal, yet strong and melts at 1084ºC. It is a good conductor of heat and electricity. Since copper is available in abundance and economical, have attracted a lot of interest in recent years as a viable disinfectant. The preference of copper nanoparticles in this study is due to its antibacterial[12], antiviral[13] and antifungal[14] properties. Since, incorporation of copper nanoparticles into the irreversible hydrocolloid impression material enhances its antimicrobial activity there might be any potential alterations of mechanical and physical properties of the impression material. Hence, this study is undertaken to evaluate the physical properties of irreversible hydrocolloid impression materials incorporated with copper nanoparticles such as tear strength and flowability at various concentrations. Tear strength is defined as the maximum force required to tear a test specimen in a direction normal to (perpendicular to) the direction of the stress. Tear strength of irreversible hydrocolloid impression material is poor so, it plays an important role when an impression encounters a mechanical undercut of the hard tissues during impression making. Detachment of irreversible hydrocolloid impression material from the tray can result in inaccuracies of the cast which is the fundamental disadvantage during the fabrication of prosthesis.[15] Therefore, the tear strength of irreversible hydrocolloid impression material forms an essential drawback for its application in clinical use. Irreversible hydrocolloid impression material is widely used due to its superior flow characteristic. Flow is indirectly proportional to viscosity of the particular material. Any alteration in the viscosity of a dental material can impede its flow characteristic.[16] Since, there is paucity of literature available pertaining to addition of copper nanoparticles to irreversible hydrocolloid impression material and its effect on physical and mechanical properties at different concentrations. Hence, this study is undertaken to evaluate and compare the tear strength and flowability of irreversible hydrocolloid impression material incorporated with copper nanoparticles at 0.25wt%, 0.50wt%, 1.0wt%.

Materials and methodology

I. Fabrication of Irreversible Hydrocolloid impression material test specimens for tear strength evaluation
II. Incorporation of copper nanoparticles into Irreversible Hydrocolloid impression material at 0.25 wt%, 0.5 wt% and 1.0 wt% respectively.
III. Grouping of Samples.
IV. Testing of specimens for Tear Strength
V. Measurement of flowability.

I. **Fabrication of irreversible hydrocolloid impression material test specimens for tear strength evaluation: Mould preparation:** An acrylic sheet of 0.5mm thickness is laser cut according to dimensions 8cm X 1cm X 0.5cm. Similarly, five moulds spaces have been laser cut on the customized acrylic mould to obtain six samples of Irreversible Hydrocolloid impression material.

Fabrication of Samples: Petroleum jelly was smeared on the inner walls of customized acrylic mould spaces. This acrylic mould was mounted on a smooth surfaced glass slab. 8.4 grams of irreversible hydrocolloid impression material IMPRECEED (GC Corporation Tokyo, Japan) is weighed and mixed with 20ml of distilled water in alginator in accordance to manufacturer recommendations. The manipulated irreversible hydrocolloid impression material was poured in to the customized acrylic mould spaces (fig.1). A glass slab was placed over which a standard weight of 1kg was kept to ensure a uniform thickness of the specimen (fig.2). After the irreversible hydrocolloid material is set, the test specimens were retrieved carefully from the mould (fig.3&4). Similarly, 15 samples are fabricated for each concentration of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.25wt%, 0.5wt%, 1.0wt%.

II. **Incorporation of copper nanoparticles into irreversible hydrocolloid impression material:** Copper nanoparticles (procured from Nano Wings Pvt. Ltd Khammam) was incorporated into the irreversible hydrocolloid impression material in Vortex Machine for achieving a homogeneous mixture. The concentrations of incorporated copper nanoparticles in each group are:

- 0.25 wt% i.e., 75.3 grams of copper nanoparticles to 1000 grams of irreversible hydrocolloid impression material.
- 0.50 t% i.e., 150.6 grams of copper nanoparticles to 1000 grams of irreversible hydrocolloid impression material.
- wt% i.e., 301 grams of copper nanoparticles to 1000 grams of irreversible hydrocolloid impression material.

III. **Grouping of Samples: A total of 120 samples are fabricated and divided in to 4 groups (1 control group and 3 experimental groups) consisting of 30 samples in each group. 30 samples are further divided into 2 subgroups each consisting of 15 samples to evaluate tear strength and flow.**

Group A: [Control Group]

1. Sub Group A1: 15 samples of irreversible hydrocolloid impression material to

evaluate tear strength [Ats].

2. Sub Group A2: 15 samples of irreversible hydrocolloid impression material to assess flowability [Af].

Group B: 0.25 wt% [experimental group 1]

1. Sub Group B1: 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.25 wt% to evaluate tear strength [Bts].
2. Sub Group B2: 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.25 wt% to assess flowability [Bf].

Group C: 0.5 wt% [experimental group 2]

1. Sub Group C1: 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.5 wt% to evaluate tear strength [Cts].
2. Sub Group C2: 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.5 wt% to assess flowability [Cf].

Group D: 1.0 wt% [experimental group 3]

1. Sub Group D1**:** 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 1.0 wt% to evaluate tear strength [Dts].
2. Sub Group D2: 15 samples of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 1.0 wt% to assess flowability [Df].

IV. Testing of Specimens for Tear Strength

The equipment used for testing the specimens for tear strength is strain gauge. The fabricated irreversible hydrocolloid impression material specimens of dimensions 8cm X 1cm X 0.5cm were placed in between the jigs of the strain gauge (fig.5). Load was applied and gradually increased till the specimen tears. The load at which the specimen tears was noted from the console of the strain gauge. Similarly, the tear strength of irreversible hydrocolloid impression material incorporated with copper nanoparticles of 0.25wt%, 0.5wt%, 1.0wt% are tested and recorded.

V. Measurement of Flowability

Flowability is measured by comparing the circumference of the impression discs. These are made by injecting 0.5ml hydrocolloid irreversible impression material IMPRECEED (GC Corporation Tokyo, Japan) onto a glass slab using a 2ml disposable syringe within 60 seconds of mixing as recommended by the manufacturer (fig.6). Another glass slab was then placed on top of the impression material (fig.7), and a standard weight of 1.5kg is placed on the outer surface of the upper glass slab. After the final set, the weight was removed and the perimeter of the impression disc was measured with the help of a matlab software called edge detector. The sample was scanned with the help of a scanner (fig.8). The scanned impression discs are programmed in the mat software (fig.9). This program detects the perimeter and diameter of the discs, thus the flowability is evaluated. Similarly, all the 15 samples of each group are tested for flow and recorded.

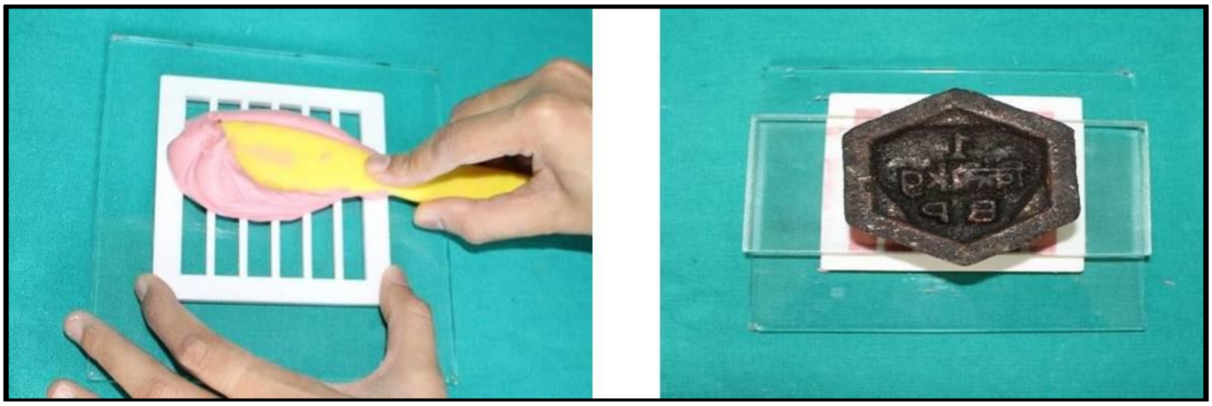

Figure 1 and 2

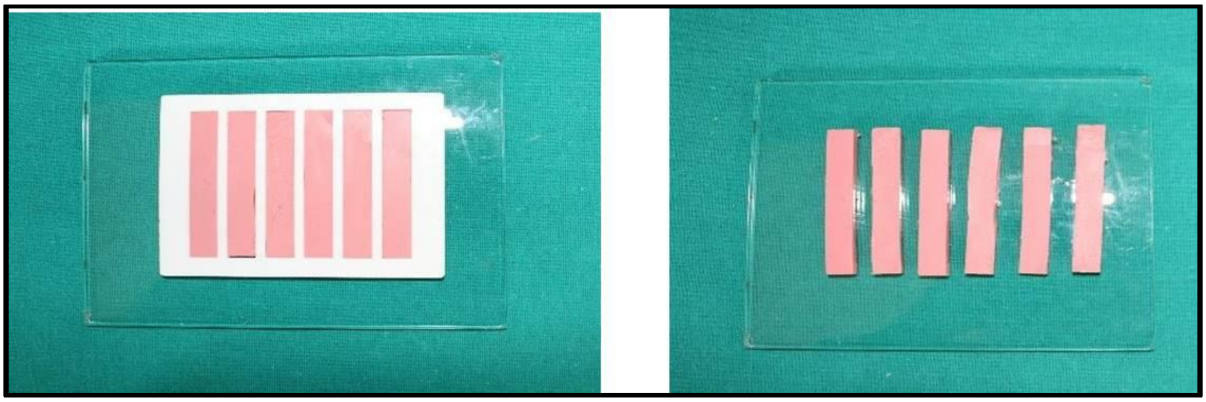

Figure 3 and 4

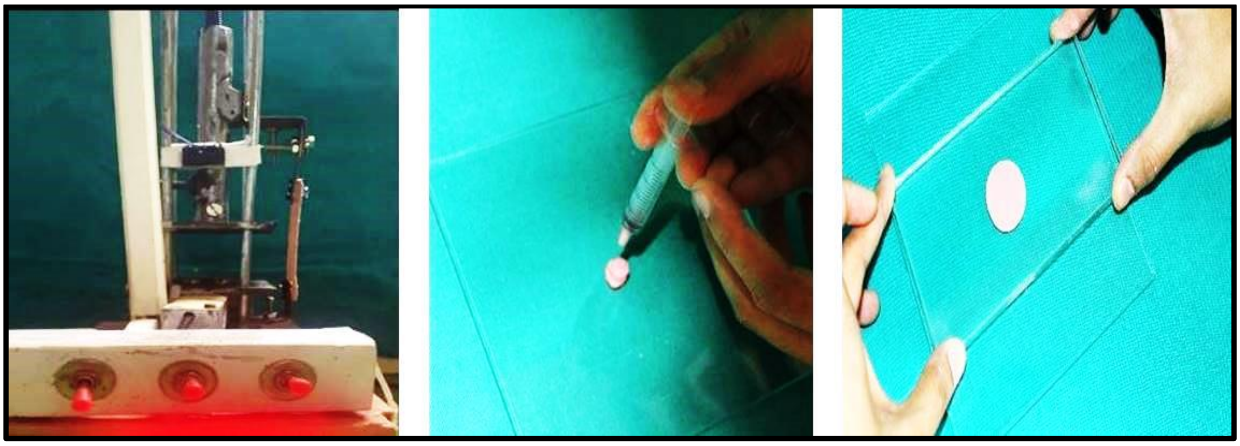

Figure 5, 6 and 7

Figure 8 and 9

Results

Evaluation of Tear Strength

For tear strength, Mann whitney U test showed statistically significant differences ($p < 0.05$). It was observed that the mean tear strength was higher in control group A1 (241±2.84). The mean tear strength was lower in samples of Group B1 (166.7±23.2) (irreversible hydrocolloid impression material incorporated with 0.25wt% copper nanoparticles) followed by Group C1 (94.7±20.6) (irreversible hydrocolloid impression material incorporated with 0.5wt% copper nanoparticles) and Group D1 (64.2±21.6) (irreversible hydrocolloid impression material incorporated with 1.0wt% copper nanoparticles). (Table 1&2)

Evaluation of Flowability

For tear flowability, Mann whitney U test showed statistically significant differences (p <0.05). It was observed that the mean flowability was higher in Control Group A2 (3.7±0.02). The mean tear strength was lower in Group B2 (3.6±0.04) (irreversible hydrocolloid impression material incorporated with 0.25wt% copper nanoparticles) followed by Group C2 (3.5±0.05) (irreversible hydrocolloid impression material incorporated with 0.5wt% copper nanoparticles) and Group D2 (3.3±0.04) (irreversible hydrocolloid impression material incorporated with 1.0wt% copper nanoparticles). (Table 3&4)

Table 1: Comparison of mean tear strength (in gm/cm2) between 4 groups using Mann Whitney U test

Comparison of mean tear strength (in gm/cm2) between 4 groups using Mann Whitney U test					
Group	**N**	**Mean**	**SD±**	**Minimum**	**Maximum**
Group A1	15	241.2667	2.84019	237.00	248.00
Group B1	15	166.7333	23.27005	119.00	201.00
Group C1	15	94.7333	20.63100	48.00	125.00
Group D1	15	64.2667	21.68761	18.00	99.00

Table 2: Comparison of tear strength of Group A1, Group B1, Group C1 and Group D1

Comparison of tear strength of groups A1, B1, C1, D1 Using Kruskal Wallis test						
Group	**N**	**Mean**	**SD±**	**Mean rank**	**Chi-Square value**	**P value**
Group A1	15	241.2667	2.84019	53	52.308	**0.000***
Group B1	15	166.7333	23.27005	37		
Group C1	15	94.7333	20.63100	20.83		
Group D1	15	64.2667	21.68761	10.3		
Kruskal Wallis test; p≤0.05 considered statistically significant						

Table 3: Comparison of mean flowability (cms) between 4 groups using Mann Whitney U test

Comparison of mean flowability (cms) between 4 groups using Mann Whitney U test					
Group	**N**	**Mean**	**SD±**	**Minimum**	**Maximum**
Group A2	15	3.7146	0.02520	3.68	3.77
Group B2	15	3.6251	0.04783	3.53	3.69
Group C2	15	3.5219	0.05065	3.43	3.59
Group D2	15	3.3915	0.04507	3.30	3.45

Table 4: Comparison of flowability of Control Group A2, Group B2, Group C2 and Group D2

Variable	**N**	**Mean**	**SD ±**	**Mean rank**	**Chi Square value**	**P value**
Group A2	15	3.7146	0.02520	52.8	52.951	**0.000***
Group B2	15	3.6251	0.04783	37		
Group C2	15	3.5219	0.05065	23.8		
Group D2	15	3.3915	0.04507	8.33		
Kruskal Wallis test; p≤0.05 considered statistically significant						

Discussion

In restorative dentistry, making impressions of the hard and soft tissues is one of the most essential constituents for a successful prosthodontic outcome. Impression materials are used to make accurate replicas of the oral tissues involving partial or completely edentulous arches.[4] A wide variety of impression materials are currently available which includes elastic impression materials such as hydrocolloids, nonaqueous synthetic elastomeric polymers, and nonelastic materials such as impression plaster, impression compound and zinc oxide eugenol impression pastes etc.,[9] Among these impression materials, irreversible hydrocolloid i.e., alginate is most commonly used as it possesses the desirable qualities such as good surface detail replication, non-toxic and non-irritant, low cost, ease of manipulation and are elastic enough to be drawn from the undercuts without distortion. Irreversible hydrocolloid impression materials are hydrophilic in nature and this property facilitates making of precise impressions in the presence of saliva or blood. It has a low wetting angle and hence full arch impressions are easily made.[19] Alginates, also have few drawbacks such as syneresis, imbibition, four-dimensional instability etc., To overcome some of these drawbacks, extended pour alginates, dust free alginates, chromatic alginates and self- disinfecting alginates were being introduced into the market. Although, care should be exercised for every step of fabrication of prosthesis, impressions are considered to be one of the largest routes for transfer of the potentially infectious material. Saliva, blood and plaque- contaminated impressions may harbour pathogenic organisms and may transmit from patients to dental personnel who handle the impression or subsequent casts. Cross-contamination control is the prevention of transmission of infectious agents between patients, dentists and dental staff within a clinical and laboratory environment. The dental profession is becoming increasingly aware of the importance of cross-contamination control in preventing the dissemination of disease in the dental environment. An increase in population of debilitated and immunocompromised patients (as exemplified by advancing age, existing diseases, chemotherapeutic regimes etc.,) are being treated, particularly in prosthodontics. Consequently, prosthodontic patients are a high-risk group relative to their potential to transmit infectious diseases as well as their susceptibility to acquire them. The dental profession must assume that every patient treated is a cross-infection risk and adopt appropriate control measures to break the chain of infection.[17] Irreversible hydrocolloids are one of the most debated materials in terms of their disinfection process. It even has certain limitations, such as poor dimensional stability because of which the impressions are to be immediately poured and due to their hydrophilicity, it facilitates the highest retention of bacteria[18] due to the spaces between the gel structures. Researchers have proposed many methods of disinfection for irreversible hydrocolloid impressions such as immersion and spraying. In immersion, there is propensity for alginates to imbibe water which in turn may result in the alteration of its dimension. In an attempt to avoid this, spray technique was proposed.[20] Spraying the surface of the impression did not much affect the properties of the impression material. However, some authors consider that spray disinfection is ineffective from a microbiological point of view and diminished replication of surface details along with change in surface characteristics.[21,22] To overcome these drawbacks disinfectant impregnated irreversible hydrocolloid impression materials have been developed.[23,24,25,26] The self-disinfectant impression materials also have an added advantage in reducing the time required for an extra chair side procedure for disinfection. Recent studies have suggested that incorporation of irreversible hydrocolloid impression material with dodecyl-dimethyl ammonium chloride, chlorhexidine acetate etc., and also nanoparticles such as copper, silver, zinc oxide, copper oxide exhibited increased antimicrobial activity.[26,27] Nanotechnology has become one of the most active research areas in the recent decades, especially in health sciences.[28] Nanoparticles (NPs) are discrete clusters of atoms with a wide range of medical applications, including cancer therapy, drug delivery, tissue engineering, regenerative medicine, biomolecules detection, and also as antimicrobial agents.[29] NPs are gaining momentum in dentistry due to their physicochemical and biological properties, including biocompatibility, size, charge, large surface area, strength, solubility, chemical and surface reactivity, color, high stability, and thermal conductivity. Such properties have allowed the development of new, innovative materials and the improvement of their functions.[28] The principle behind the usage of nanoparticles is that alteration of filler size is considered responsible for the enhanced performance of the material.[11] In the present study copper is preferred because copper ions either alone or in copper complexes, have been used for centuries to disinfect liquids, solids and human tissues[30] and also because of its low cost, physical and chemical stability and ease of mixing with irreversible hydrocolloid impression material.[31] Also, it has been proved that copper nanoparticles exhibit bactericidal, virucidal and fungicidal properties. Some studies concluded that incorporation of copper nanoparticles into irreversible hydrocolloid impression material exhibits improved efficacy of antimicrobial activity.[27] In the present study, Percentage of addition of copper nanoparticles i.e., 0.25 wt%, 0.5 wt% and 1 wt% was standardized in accordance with the earlier studies conducted by Kishore Ginjupalli et al (2016).[27] Incorporation of copper nanoparticles into irreversible hydrocolloid impression material definitely enhances its antimicrobial activity contrarily there might be possible alterations in their mechanical and physical properties which needs to be evaluated. Since, no literature is available, this study investigates the physical properties of irreversible hydrocolloid impression materials incorporated with copper nanoparticles such as tear strength and flowability at various concentrations. Tearing or deformation of an alginate impression can result in inaccuracies of the gypsum cast which is a fundamental requisite for the fabrication of any intraoral or extraoral prosthetic appliance. Therefore, adequate strength of alginate impression materials is important for determining the performance of these products.[32] Tear strength is the maximum force required to tear a test specimen in a direction normal to (perpendicular to) the direction of the stress.[4] As listed in Table 1 the mean tear strength values of Group A1 (control), Group B1, C1 and D1 were (241.2±2.84) gm/cm^2, (166.7±23.2) gm/cm^2, (94.7±20.6) gm/cm^2, (64.2±21.6) gm/cm^2 respectively. There is a high statistically significant difference between the obtained values ($p \leq 0.05$). This shows that there is progressive decrease in the values of tear strength on addition of increased concentrations of copper nanoparticles in irreversible hydrocolloid impression material. Highest tear strength was observed for Group A1 followed by Group B1, Group C1 and Group D1. The decrease in the tear strength of groups B1, C1 and D1 maybe due to weakened polymeric crosslink chains between copper nanoparticles and the sodium alginate. Copper nanoparticles hinders the gelation of sodium alginate to form calcium alginate. This was also in accordance with study conducted by Judith Díaz-Visurraga et al (2012)[33], on the intermolecular interaction between antibacterial copper nanoparticles (Cu NPs) and sodium alginate (NaAlg) by Fourier transform infrared spectroscopy (FT-IR) and to process the spectra applying two-dimensional infrared (2D-IR) correlation analysis. They concluded that the average particle size, polydispersity, and phase composition of Cu NPs depended mainly on their ratio. Likewise, antibacterial activity of Cu NPs was affected by their phase composition because of the carboxylate groups in polymer chains, the structural changes of Cu NPs are different from those of sodium alginate. NaAlg acted as a size controller and stabilizing agent of Cu NPs, due to their ability to bind strongly to the metal surface. Flowability of the material in particular depends on the viscosity due to the size (molecular weight) and concentration of the solution. Flow is indirectly proportional to viscosity of the particular material. Irreversible hydrocolloid impression material is extensively used as an impression material due to its superior flow characteristic. Any alteration in the viscosity of a dental material can impede its flow characteristic.[16] As listed in Table 3 the mean flowability values of Group A2 (control), Group B2, C2 and D2 were (3.7±0.02)cms, (3.6±0.04)cms, (3.5±0.05)cms and (3.3±0.04)cms respectively. There is a high statistically significant difference between the obtained values at $p \leq 0.05$. These results showed that there is gradual decrease in flow values on addition of increased concentrations of copper nanoparticles in irreversible hydrocolloid impression material. Highest values of flow were observed for Group A2 (control) followed by Group B2, Group C2 and Group D2. This decrease in the flow of Groups B2, C2 and D2 are possibly due to the increased viscosity of the irreversible hydrocolloid impression material due to inclusion of copper nanoparticles at various concentrations. Since, the molecular weight of copper is 63.5U, this may contribute for increased viscosity of the material. Since, flow is directly proportional to viscosity, incorporation of copper nanoparticles into irreversible hydrocolloid impression material at 0.25 wt%, 0.5 wt% and 1.0 wt% increases the viscosity thereby impeding its flow which is in accordance with the earlier studies.[27]

Conclusion

Within the limitations of the present study conducted by incorporating 0.25 wt%, 0.5 wt% and 1.0 wt% copper nanoparticles in to irreversible hydrocolloid impression material to evaluate and compare its tear strength and flowability, the following conclusions were drawn:

1. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 0.25 wt% (Group B1) decreased the tear strength values as compared to Control Group A1.
2. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 0.5 wt% (Group C1) decreased the tear strength values as compared to Control Group A1 and Group B1.
3. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 1.0 wt% (Group D1) decreased the tear strength values as compared to Control Group A1, Group B1 and Group C1.
4. Among the Groups tested (B1, C1, D1), the tear strength values of irreversible hydrocolloid impression material decreased with addition of copper nanoparticles from 0.25 wt%, 0.5 wt% and 1.0 wt% respectively. The test specimens of Group A1 (unmodified) showed the highest values in comparison with Group B1, Group C1 and Group D1 (modified) in descending order.
5. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 0.25 wt% (Group B2) decreased the flowability as compared to Control Group A2.
6. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 0.5 wt% (Group C2) decreased the flowability as compared to Control Group A2 and Group B2.
7. Addition of copper nanoparticles to irreversible hydrocolloid impression material at 1.0 wt% (Group D2) decreased the flowability as compared to Control Group A2, Group B2 and Group C2.
8. Among the Groups tested (B2, C2, D2), the flowability of irreversible hydrocolloid impression material decreased with addition of copper nanoparticles from 0.25 wt%, 0.5 wt% and 1.0 wt% respectively. The test specimens of Group A2 (unmodified) showed the highest values in comparison with Group B2, Group C2 and Group D2 (modified) in descending order.

The limitations of the study were:

- The clinical conditions were not simulated. Even though the dimensions of the specimens were standardized, the tear strength and flowability of irreversible hydrocolloid impression material incorporated with copper nanoparticles in the presence of the saliva is not anticipated.
- The surface of samples fabricated was flat in contrast with curved topography of maxillary and mandibular arches.
- Other properties such as gel strength, setting time, working time, surface detail reproducibility were not evaluated.
- Biosafety of direct contact of copper to the oral tissues needs to be further ascertained.

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