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Formulation & Testing 0f Physicochemical Properties of Indigenously Made Phytic Acid Incorporated Glass Ionomer Cement – "An In Vitro Study"

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ABSTRACT

Background: Phytic acid (IP6), also known as myo-inositol hexaphosphate, is a naturally abundant compound, particularly prevalent in plants, It is present in edible cereals, legumes, nuts, oilseeds, and tubers.IP6 is a promising compound with potential applications across various fields of dentistry, including endodontics, restorative dentistry, and implantology.

Aim: The aim of the study is to formulate & evaluate the physicochemical properties of Ip6 incorporated Glass Ionomer cement.

Materials and Methods: Phytic acid (Ip6) liquid was prepared at 1%, 2%,5% concentrations, followed by the addition of these modified liquids at various concentrations into conventional GIC liquid. A total of 80 specimens were prepared by mixing modified liquids of various concentrations into conventional GIC powder. The specimens were grouped into four types based on the modified liquids used which is as follows Group 1 is conventional GIC, Groups 2, 3, and 4 included 1%, 2%, and 5% phytic acid incorporated GIC respectively. The compressive strength of the specimens were assessed using a universal testing machine.

Results: The results of the study showed a statistically significant increase in compressive strength with a mean value of (56.40 + 29.63 MPa) in 5% incorporated GIC, followed by 2% incorporated GIC (40.83 $\pm$ 19.54 MPa)and 1% showed the lowest compressive strength (25.69+11.64 MPa).

Conclusion: Phytic acid incorporation into Glass Ionomer Cement (GIC) is a game-changer, significantly boosting its compressive strength, especially at higher concentrations of 5%. This innovative enhancement transforms GIC into a more robust and durable restorative material while harnessing the unique benefits of IP6, including biocompatibility, antioxidant, and cariostatic properties.

1. INTRODUCTION

Phytic acid, chemically known as myo-inositol hexaphosphate (IP6), is a compound which is plenteous in nature, particularly in plants, where it constitutes 1–5% of the weight of edible cereals, legumes, nuts, oilseeds, and tubers.[1] The average daily intake of phytate in individuals consuming vegetarian diets ranges between 2000 and 2600 mg.[2] Once ingested, it is instantly absorbed in the gastrointestinal (GI) tract and enters the bloodstream. Studies have demonstrated that IP6 when employed as an additive improves the chemical and physical properties of cement . Sodium phytate, a sodium salt of phytic acid, has been demonstrated to limit the growth of Escherichia coli in raw and cooked meats such as beef, chicken, and pork.[3] Another study revealed that phytic acid produced from rice bran inhibited the growth of both Salmonella typhimurium and E. coli.[4] Additionally, in vivo studies have shown that sodium phytate exhibits cariostatic activity.[5] Kaufman and Kleinberg ascribe the cariostatic effects of phytic acid and its derivatives, primarily due to its ability to diminish the solubility of calcium, fluoride, and phosphate, which are essential components of dental enamel..[6] Interestingly, dental cements containing IP6 have demonstrated an increased calcium concentration in their surrounding medium, likely due to it's capacity to form insoluble bonds with calcium, a property that can enhance dentine formation in exposed dental pulps.[7] Despite their widespread use, materials such as Biodentine™ and MTA exhibit several limitations, including extended setting times, poor handling properties, and low resistance to washout.[8] IP6 has been identified to successfully shorten the setting time of these cements at particular concentrations without impairing their diametral tensile strength. This effect was more pronounced with Biodentine™ compared to MTA.[9] The hydrophilic characteristic of IP6 is assumed to be the cause of the accelerated setting time, as it works in concert with calcium silicate cements that set through hydration processes.

This effect is further amplified by the strong binding of the highly negatively charged phosphate groups in IP6 to metallic ions in the cement.[10] It has also been demonstrated that IP6 alters the way proteins bind to tooth surfaces and suppresses the production of brushite and hydroxyapatite crystals.[11] These effects are attributed to its structural resemblance to pyrophosphate, a crucial polyphosphate that restricts the formation of calculus.[12]In a study by Milleman et al., an experimental dentifrice containing 0.85% w/w IP6 demonstrated superior stain removal efficacy compared to a control dentifrice, without increasing abrasivity. This highlights the potential of IP6 to enhance stain removal in a manner similar to condensed polyphosphates.[13] Glass Ionomer Cement (GIC) is a cornerstone material in pediatric dentistry due to its unique properties, including fluoride release, biocompatibility, and chemical adhesion to dental tissues. However, GIC is limited by its low compressive strength, poor wear resistance, and sensitivity to moisture during setting, which restrict its use in high-stress-bearing areas such as posterior restorations.[14] Innovations in GIC formulations are crucial to improving its mechanical properties while maintaining its biological benefits. IP6 has shown promising attributes, such as biocompatibility, antioxidant activity, and cariostatic effects, alongside its ability to improve the mechanical properties of dental cements.[15] Incorporating IP6 into GIC formulations could provide a dual benefit: leveraging its biological advantages while strengthening the material to create a more versatile and durable restorative option. Currently, there is no literature available on the incorporation of phytic acid into GIC, presenting an opportunity for further research.

2. MATERIALS AND METHODS

The present study was conducted in the Department of pediatric and preventive dentistry

Peoples College of Dental Sciences and Research Centre. Firstly, Phytic acid (Ip6) liquid was prepared at 1%,2%,5% concentration, followed by addition of these modified liquids at various concentration into conventional GIC liquid. A total of 80 specimens were prepared by mixing modified liquids of various concentration into conventional GIC powder. The specimens were grouped into four types based on the modified liquids used which is as follows Group 1 is conventional GIC, while Groups 2, 3, and 4 included 1%, 2%, and 5% IP6, respectively. The specimen in the dimension of 4mm diameter and 6mm height were fabricated in polyethylene tube (Fig 1).[16] Each sample was ground flat using 600-grit silicon carbide paper an hour after mixing. After that, a compressive load was applied along the specimens longitudinal axis while they were positioned with their flat ends between the platens of a universal testing apparatus (Fig. 2). The measurements were carried out at a speed of 0.75 mm/min, room temperature of 22 °C, and relative humidity of 45% in accordance with ISO standard 7489; 1986. Each specimen's CS, measured in N/mm2, was determined using the formula;

$$C \text{ x } S = 4 \cdot F \pi \cdot d2 \qquad (1)$$

where *F* (N) is the max. force and *d* (mm) is the diameter of the specimen

Fig1- Samples in polyethylene tube

Fig 2-Universal testing machine

3. RESULTS

The results of the current study revealed statistically high compressive strength in 5% Phytic acid incoporated GIC with a mean value of 56.4000 + 29.6383 MPa (Table 1). 2% Phytic acid incorporated GIC exhibited a substantial improvement in compressive strength as well. The average compressive strength for this group was 40.831 ± 19.547 MPa. Which was slightly lower than the 5% Phytic acid incorporated GIC. However 1% Phytic aicd Incorporated GIC showed decreased compressive strength (25.69+11.64 MPa) compared to 5% ,2% Phytic aicd incorporated GIC and conventional GIC. On comparing, it was observed that 5% Phytic acid incorporated GIC showed significant difference in compressive strength compared to conventional GIC (p=0.001) as shown in Table2 and Fig 3. It was also noted that 5% Phytic acid incorporated GIC showed a significant difference in compressive strength compared to 1% Phytic aicd incorporated GIC (0.045).While there was no significant difference in compressive strength of 2% Phytic acid incorporated GIC with conventional GIC and 1% Phytic acid incorporated GIC (p.0.05).

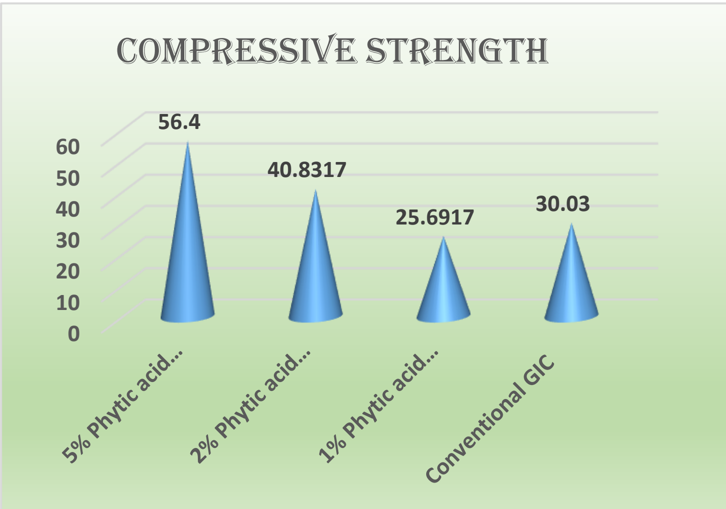

Fig 3 –Comparative analysis of compressive strength

Table 1: Comparative evaluation of compressive strength between groups

Groups	N	Mean	S.D
5% Phytic acid reinforced GIC	20	56.4000	29.63883
2% Phytic acid reinforced GIC	20	40.8317	19.54790
1% Phytic acid reinforced GIC	20	25.6917	11.64094

Conventional GIC	20	30.0300	.86344
F statistic	3.215		
df	3		
P value	.045*		

** =Significant; NS = Not Significant*

Table 2: Post hoc evaluation of compressive strength between pairs

Pairs	**Mean difference**	**Std. Error**	**Significance**
5% Phytic acid reinforced GIC versus 2% Phytic acid reinforced GIC	15.56833	10.78903	.489 (NS)
5% Phytic acid reinforced GIC versus 1% Phytic acid reinforced GIC	30.70833*	10.78903	.045*
5% Phytic acid reinforced GIC versus Conventional GIC	26.37000	10.78903	.001*
2% Phytic acid reinforced GIC versus 1% Phytic acid reinforced GIC	15.14000	10.78903	.512 (NS)
2% Phytic acid reinforced GIC versus conventional GIC	10.80167	10.78903	.750 (NS)
1% Phytic acid reinforced GIC versus conventional GIC	-4.33833	10.78903	.977 (NS)

** =Significant; NS = Not Significant*

4. DISCUSSION

The glass Ionomer cement has enormous potential in caries management in children due to its inherent and unique properties of fluoride release and uptake, chemical bonding to enamel and dentin, coefficient of thermal expansion similar to natural tooth tissue, biocompatibility, and reduced moisture sensitivity in comparison to resins.[17]

Despite many advantages, conventional glass Ionomer cements have some limitations like compromised mechanical properties such as low compressive strength, fragility, slow-setting, and poor wear resistance thereby limiting their use in posterior regions of the oral cavity.[18,19]

Our study demonstrated a significant increase in compressive strength, with a highest mean value of **56.40 ± 29.63 MPa** achieved at 5% IP6 concentration. This enhancement directly addresses a major limitation of conventional GIC, its relatively low mechanical strength making the modified material more robust and suitable for load-bearing clinical applications**.** The incorporation of IP6 not only improves mechanical properties but also introduces potential benefits such as antioxidant activity, biocompatibility, and cariostatic properties, which are advantageous in restorative dentistry. In contrast ,**Leon et al. (2006**) investigated the effect of oxalic acid on GIC and found no significant change in compressive strength across concentrations ranging from 0% to 7%.[19]These modifications aim to enhance the mechanical properties of GIC without compromising its beneficial characteristics. Both our study and **Nassar et. al (2020)** explore the potential of IP6 in dental applications, but they address distinct aspects of its functionality. While our study focuses on enhancing the mechanical properties of Glass Ionomer Cement (GIC), their study investigates the effects of IP6 on resin-dentin adhesion, particularly in the context of sodium hypochlorite (NaOCl)-treated dentin.[20] Studies have highlighted that IP6 treatment of dentin significantly reduces collagen degradation compared to phosphoric acid (PA). This effect likely contributes to the lower incidence of adhesive failures in IP6-treated dentin by enhancing the stability of the exposed collagen network.[21] **Kong et al. (2015)** further demonstrated that IP6 gently etches dentin, effectively removing the smear layer and smear plugs without causing excessive demineralization, as seen with Phosphoric acid and EDTA. This controlled etching not only preserves dentin integrity but also results in higher bond strength. Moreover, IP6 exhibits the unique ability to inhibit bacterial collagenase activity, providing additional protective benefits to the dentin. [22] This ability of IP6 suggests its potential to enhance the bond strength of GIC, thereby improving its durability and long-term performance. According to **Rania et al. (2021)** IP6 has potent antimicrobial and antibiofilm activity against a range of microorganisms, including *E. faecalis* and *Candida albicans*. At concentrations as low as 0.5–5%, IP6 exhibited rapid bactericidal effects, with 5% IP6 eliminating *E. faecalis* within 30 seconds. This highlights its potential as an effective endodontic irrigant and a novel solution to increase the antimicrobial resistance of GIC.[23] As per the findings of **Uyanik et al .(2019)** it was observed that at specific concentrations, IP6 can significantly reduce the setting time of calcium silicate-based cements without compromising their diametrical tensile strength, with this effect being more pronounced in Biodentine™ compared to MTA which helps to overcome its limitation like long setting time.[9]While Uyanik et al. emphasized the role of IP6 in optimizing setting time for calcium silicate-based cements, our study highlights its potential to improve the mechanical properties of GIC. Additionally, previous research has shown that IP6 improves the mechanical properties of zinc phosphate cements. **Li et al. (1994)** noticed in his research that enhancing the concentration of IP6 from 0% to 2% doubled the compressive strength, replacement of 3–5% of phosphoric acid with IP6 resulted in maximum compressive strength. This improvement was attributed to the higher stability of zinc phytate compared to zinc phosphate, which also reduced the leach from the resultant cement.[24]In our study, the incorporation of 5% IP6 incorporated GIC resulted in a remarkable increase in compressive strength compared to conventional GIC, without compromising its inherent properties. The probable reason could be the ability of phosphate groups in Ip6 to interact with metal ion (eg calcium , aluminum) present in the material which promotes additional crosslinking within the matrix of cement leading to a denser, more interconnected structure that enhances compressive strength. Further investigations are required to assess its cytotoxicity or potential effects on oral tissues, which are crucial for clinical application. In vitro design is the major limitation of this study, thus further clinical investigation regarding the longevity of Phytic acid incorporated GIC in the oral cavity should be carried out to authorize its use in clinical dentistry.

5. CONCLUSION

Phytic Acid incorporation into Glass Ionomer Cement (GIC) is a game-changer, significantly boosting its compressive strength, especially at higher concentrations of 5%. This innovative enhancement transforms GIC into a more robust and durable restorative material, while harnessing the unique benefits of Phytic acid, including biocompatibility, antioxidant, and cariostatic properties. The 5% Phytic acid-incorporated GIC stands out as a durable and versatile material, capable of withstanding high masticatory forces and offering added protection against caries. By combining strength, functionality, and biological benefits, this innovative formulation addresses the limitations of conventional GIC, paving the way for its use in a wide range of restorative applications.

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