



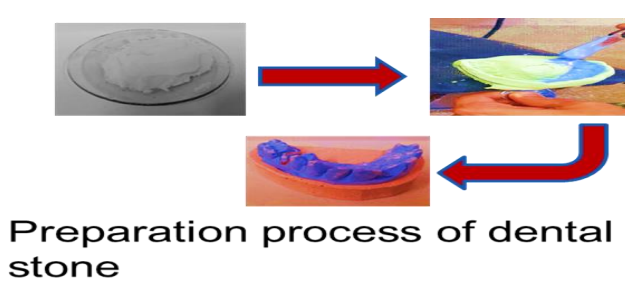
Sustainable and cost-effective production of gypsum-based plasters for dental applications from used dental products and from local minerals

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Abstract : The dental industry generates a significant amount of waste in the form of used dental products, including gypsum-based plaster materials. This waste poses environmental challenges and increases disposal costs. In response to these issues, this research explores a sustainable and cost-effective approach to producing dental plaster materials through recycling used dentures and extracting gypsum from local minerals. Through a combination of chemical and physical processes, used dental products, such as discarded plaster casts and impressions, were reclaimed. Chemical dissolution and purification techniques were employed to extract the desired calcium sulphate compounds, which were then carefully reconstituted into gypsum and hemihydrate plaster suitable for dental applications. Alternatively, slaked lime which is extracted from local minerals, and sulphuric acid were used as basic components for manufacturing gypsum by bottom-up wet chemical method. Purified regenerated acid sulphate sources were introduced instead of pure imported sulphuric acid. By leveraging indigenous calcium-rich minerals like dolomite, and corals, the study promotes regional self-sufficiency by minimizing dependence on external sources. Innovative extraction and processing methods were designed to efficiently convert these local minerals into a sustainable and readily available source of gypsum. The parameters of dental plasters are optimized by adding a mixture of zirconium oxide (ZrO₂), and silicon dioxide (SiO₂) which is used as an additive to optimize the retention time, and strength of the dental plasters, whereas sodium silicate alone was used as a binder. All those additives are extracted from locally available zircon sand. Furthermore, the characterization of the materials developed were done using Fourier transformed infrared (FTIR) spectroscopy, thermogravimetric analysis (TGA), LASER light scattering based particle size analysis and mechanical property measurements which were compared with those of commercial products which show compatible results. In conclusion, the culmination of these efforts is a dual-pronged approach that offers substantial benefits to the dental industry and the environment. The developed methods hold the promise of scalability and commercial viability, paving the way for a more circular and resource-efficient dental sector. Ultimately, this study envisions a paradigm shift in dental material sourcing, characterized by minimized waste, reduced environmental impact, and enhanced economic resilience.

Introduction

- The dental industry generates a significant amount of waste in the form of used dental products, such as dental plaster and stone models (gypsum products), impression materials, and plaster models
 - Gypsum : naturally occurring, white powdery mineral
chemical name : calcium sulphate dihydrate (CaSO₄·2H₂O)
 - Gypsum products used in dentistry : based on calcium sulphate hemihydrate (CaSO₄·1/2H₂O)
- Applications of gypsum products in dentistry involve the below reaction,



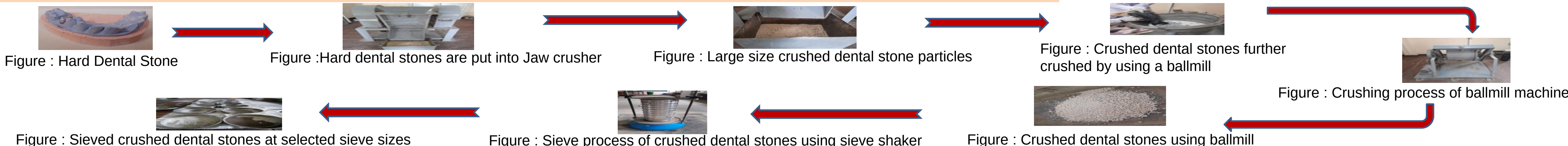
Preparation process of dental stone

Aim : Synthesize dental plaster and stone from used dental plaster and stone models which are currently disposed

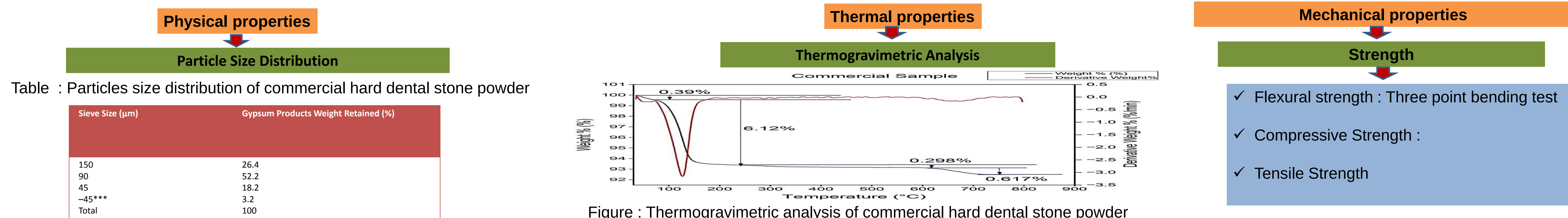
Proposed Procedure

1. Preparation and recycling process – Hemihydrate calcium sulphate

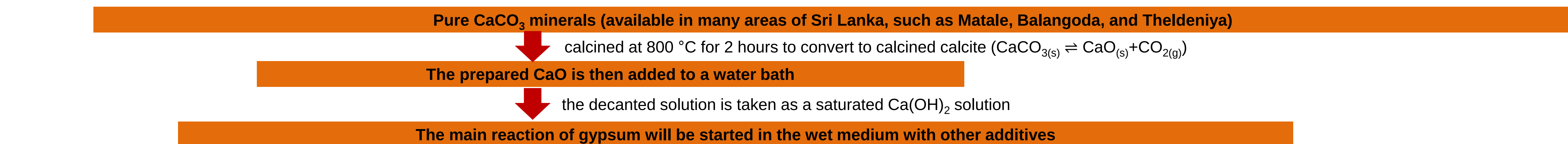
1.1 Dental stones are crushed and sieve to get the powder form



1.2. Analysis of Used Dental stones and commercial dental stones



2. Synthesis of gypsum and hemihydrate calcium sulphate from local minerals



- Main factors : Controlling the concentrations of each ion, r.p.m of the mixing, the reaction time to make micro and nanoparticles of gypsum without adding any surfactants
- The final product of gypsum will be produced by drying, grinding, and autoclaving

3. Making acidic sulphate solution

- Slaked lime and sulfuric acid are the basic components for manufacturing gypsum by bottom-up wet chemical method (Roychand *et al.*, 2021)
- purified regenerated acid sulphate sources can be introduced instead of pure imported sulfuric acid



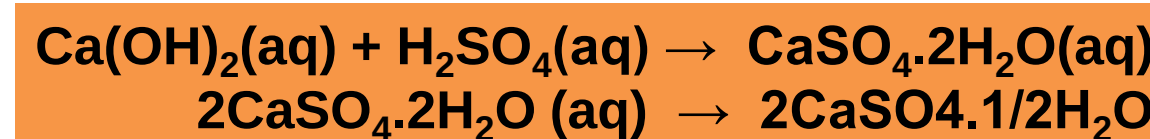
Figure : Proposed process for purification of used sulphuric acid

4. Preparation of Calcium source

- Dolomite or the corals can be used as the calcium source
- Both materials need to be calcined and leached out the calcium from the solid mixture using distilled water

5. Synthesis of gypsum and gypsum hemihydrate (Plasters) micro and nano particles

- The synthesizing method is the bottom-up method (Butscher *et al.*, 2011) by reacting, Ca(OH)₂, CaO or CaCO₃ with sulfuric acid with ambient conditions
 - the sizes and shapes of the particles can be maintained at required levels (Stawski *et al.*, 2019) by the use of required additives.
- The chemical reactions are given below,



6. Optimizing the Setting time and Strengthening with additives

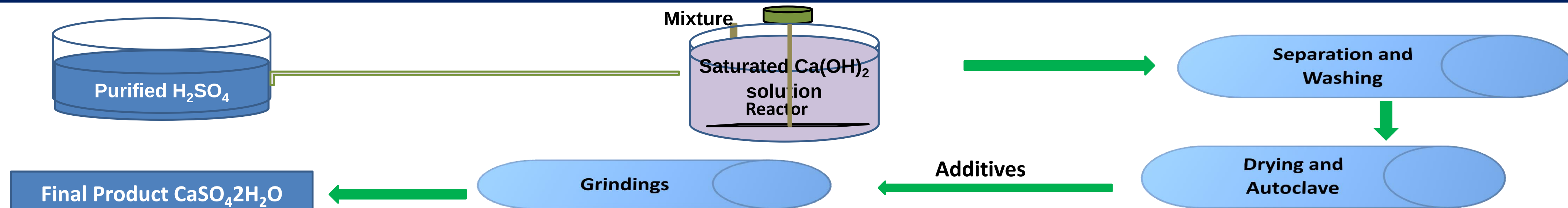
- Gypsums are categorized according to their main properties (Yilmaz, 2007), such as strength and setting time. Those parameters can be optimized by adding additives.



7. Analysis of the final product

- The final product is analyzed by X-ray diffraction spectrometer (XRD), X-ray fluorescence spectroscopy (XRF), Particle size analyzer, scanning electron microscope (SEM), strength test, and setting time analysis, and all the parameters will be compared with standard available materials

Designing a Pilot Scale Plant



Future Directions

- Further research can focus on optimizing the recycling and synthesis processes to enhance efficiency and reduce energy consumption. Additionally, exploring the mechanical and biocompatibility properties of the synthesized materials will ensure their suitability for a wide range of dental applications.

Conclusion

- This study showcases the potential for sustainable synthesis and scaling up of gypsum and hemihydrate calcium sulphate for dental applications through the recycling of used dental products and the utilization of local mineral sources. The integration of chemical and physical processes paves the way for a more environmentally friendly and economically viable dental material production process.

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