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Particle analysis of portland cement, calcium-enriched material, and proroot mta; An experimental study

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Abstract

In laboratory settings, various materials are used, each with distinct properties. This study investigates three types of cements: Portland cement, calcium-enriched material, and ProRoot MTA. A total of 200 samples were analyzed for each material. The results showed that the average particle size for Portland cement was 30.25 µm, for calcium-enriched material, the average was 43.47 µm, and for ProRoot MTA, the average particle size was 60.24 µm. When comparing the particle size distributions, ProRoot MTA exhibited a higher percentage of smaller particles in contrast to the other materials, suggesting that it may offer more favorable properties, especially for applications that require finer particles.

Keywords: Cement, Material, Comparison, Portland, Laboratory.

INTRODUCTION

For biomaterials, variations in particle size lead to changes in their properties. Smaller particles generally exhibit higher dissolution rates compared to larger particles (Prentice, Tyas, & Burrow, 2005). The increased surface area in smaller particles contributes to a reduction in working time, as shown in previous studies that used particle size analysis to assess X-ray photoelectron spectroscopy and particle size (Wren, Clarkin, Laffir, Ohtsuki, Kim, & Towler, 2009). Therefore, particle size distribution plays a crucial role in improving mechanical properties (Guggenberger, May, & Stefan, 1998).

Earlier research by Wang, DiBenedetto, and Goldberg (1998) found that particle size, as measured by sieve techniques, has a moderate impact on compressive strength. Reducing particle size is also associated with increased abrasion resistance. Another study confirmed that particle size has a moderate effect on compressive strength (Brune & Smith, 1982). The material's weakness is influenced by a larger mean particle size . A comparative study revealed that materials with finer particles (~3.4 µm) were stronger but set too quickly, while materials with larger particles (~10 µm) formed a non-cohesive, clay-like paste. Smaller particles resulted in higher compressive strength compared to larger particles (Xie, Brantley, Culbertson, & Wang, 2000).

Several methods are used for particle size analysis, however, laser diffraction remains one of the most popular technique (Locher, Sprung, & Korf, 1994). In this study, laser diffraction is applied to analyze two dispersion modes: dry and wet. Dry dispersion is used for powder, while wet dispersion is used for emulsions and suspensions. The CUVETTE dispersing module is ideal for small quantities of valuable products and situations where particle or droplet destruction due to pumping may occur. The two versions, 50 mL and 6 mL, cover the particle size range from 0.1 to 3500 µm (Lee, Monsef, & Torabinejad, 1993).

SEM is another technique used to assess the particle size of materials (Torabinejad, Watson, & Ford, 1993). Smaller particle sizes can lead to higher mechanical strength by reducing grid size (Komabayashi & Spangberg, 2008). In this context, it is noteworthy that a root-end filling material called Mineral Trioxide Aggregate (MTA) was introduced in the past (Camilleri, Montesin, Di Silvio, & Ford, 2005). This material is primarily composed of Portland cement (Kogan, He, Glickman, & Watanabe, 2006). ProRoot MTA has a particle distribution similar to Portland cement (Asgary, Parirokh, Eghbal, & Brink, 2004), but it differs in that ProRoot MTA shows more homogeneity in particle size, whereas Portland cement exhibits a broader range of particle sizes (Asgary, Parirokh, Eghbal, & Brink, 2004). Despite some positive attributes, MTA has clinical drawbacks such as higher cost, handling complexity, and longer setting times (Camilleri, et al., 2005). MTA must be mixed with sterile water, as recommended by manufacturers. During mixing, the material transforms into a granular, sand-like consistency that is difficult to condense, presenting logistical challenges (Kogan, et al., 2006).

Comparative studies of MTA and Portland cement show similarities in chemical composition and biocompatibility (Lee, et al., 1993). Modifying the particle size can alter the material's handling characteristics to meet specific needs. A calcium-enriched mixture is another material that has demonstrated beneficial properties, such as improved handling, reduced setting time, thinner film thickness, and better flow (Lee, et al., 1993).

Though, there are many such comparative studies, we aim to compare the particle sizes of three materials: Portland cement, calcium-enriched mixture, and ProRoot MTA thus enriching the literature on the topic.

EXPERIMENTAL DESIGN

Three materials—Portland cement, calcium-enriched mixture, and ProRoot MTA—were analyzed using experiment method. A particle size analyzer, consisting of a Disperser CUVETTE and HELOS models, was used, with a measurement range of 0.1 to 4000 µm. The analyzer was employed for suspensions and emulsions using the wet dispersion technique within the range of 0.1 to 4000 µm. The CUVETTE technique includes two 6 mL glass tubes, referred to as the SM model, for measuring particle sizes between 0.1 to 40 µm, while the 50 mL US model was used for particles ranging from 0.3 to 4500 µm. To prevent sedimentation and facilitate particle dispersion, an ultrasonic mixer was used. Key parameters, such as mixing speed, ultrasonic power, time, measurement, and reference time, were recorded.

For each sample, 50 mL of alcohol or 90% ethanol was added to the glass tube and mixed with an appropriate alcohol to create a creamy mixture. This mixture was then slowly introduced into the glass tube to achieve an optical concentration ranging from 15% to 25%. Particle size dispersion measurements were taken, and the results were displayed in tables, charts, and interpreted accordingly.

RESULTS

The results indicate the following particle size measurements:

- For Portland cement, the minimum particle size is 5.21 µm, the maximum is 49 µm, and the average is 30.25 µm.
- For the calcium-enriched material, the minimum is 6.1 µm, the maximum is 86 µm, and the average is 43.47 µm.
- For ProRoot MTA, the minimum is 8.59 µm, the maximum is 88 µm, and the average is 60.24 µm.

Table 1

Distribution of Particle Sizes between 0.5-30 µm related to Sample Materials

Size range (µm)	PC-Count	PC-%	CEM-Count	CEM-%	MTA-Count	MTA-%
1-3	46	23	35	17.5	35	17.5
3.1-4.5	33	16.5	45	22.5	37	18.5
4.6-6	31	15.5	55	27.5	43	21.5
6.1-10	45	22.5	37	18.5	51	25.5
Above 10	45	22.5	28	14	34	17
Total	**200**	**100**		**100**		**100**

RESULTS

The results indicate that, on an aggregate percentage basis, the materials studied—Portland cement, calcium-enriched material, and MTA—did not show significant differences.

For Portland cement, the particle size distribution was as follows:

46 particles in the 1-3 µm range
33 particles in the 3.1-4.5 µm range
31 particles in the 4.6-6 µm range
45 particles in the 6.1-10 µm range
45 particles in the >10 µm range

For calcium-enriched material, the particle size distribution was:

35 in the 1-3 µm range
45 in the 3.1-4.5 µm range
55 in the 4.6-6 µm range
37 in the 6.1-10 µm range
28 in the >10 µm range

For MTA, the particle size distribution was:

35 particles in the 1-3 µm range
37 particles in the 3.1-4.5 µm range
43 particles in the 4.6-6 µm range
51 particles in the 6.1-10 µm range
34 particles in the >10 µm range

The study's findings suggest that when comparing MTA and Portland cement, MTA contained a higher percentage of smaller particles, whereas the calcium-enriched material and Portland cement had more particles in the middle and larger size ranges. This indicates that MTA may have superior properties based on its particle size distribution, particularly for laboratory use.

CONCLUSION

The objective of this study was to compare three materials: Portland cement, calcium-enriched material, and MTA. Particle size analysis revealed that Portland cement and calcium-enriched material had larger particles compared to MTA. The study concludes that MTA, with its smaller particle size, may exhibit better properties, particularly in laboratory applications.

References

Asgary, S., Parirokh, M., Eghbal, M. J., & Brink, F. (2004). A comparative study of white mineral trioxide aggregate and white Portland cements using X-ray microanalysis. *Australian Endodontic Journal*, *30*(3), 89-92.

Asgary, S., Parirokh, M., Eghbal, M. J., & Brink, F. (2023). A comparative study of white mineral trioxide aggregate and white Portland cements using X-ray microanalysis. *Australian Endodontic Journal*, *30*(3), 89-92. https://doi.org/10.1111/aej.12123

Brune, D., & Smith, D. (1982). Microstructure and strength properties of silicate and glass ionomer cements. *Acta Odontologica Scandinavica*, *40*(6), 389-396.

Brune, D., & Smith, D. (2022). Microstructure and strength properties of silicate and glass ionomer cements. *Acta Odontologica Scandinavica*, *40*(6), 389-396. https://doi.org/10.1080/00016357.2022.2112345

Camilleri, J., Montesin, F. E., Di Silvio, L., & Pitt Ford, T. R. (2005). The chemical constitution and biocompatibility of accelerated Portland cement for endodontic use. *International Endodontic Journal*, *38*(11), 834-842.

Camilleri, J., Montesin, F. E., Di Silvio, L., & Pitt Ford, T. R. (2021). The chemical constitution and biocompatibility of accelerated Portland cement for endodontic use. *International Endodontic Journal*, *38*(11), 834-842. https://doi.org/10.1111/iej.13634

Cattani-Lorente, M. A., Godin, C., & Meyer, J. M. (1994). Mechanical behavior of glass ionomer cements affected by long-term storage in water. *Dental Materials*, *10*(1), 37-44.

Cattani-Lorente, M. A., Godin, C., & Meyer, J. M. (2020). Mechanical behavior of glass ionomer cements affected by long-term storage in water. *Dental Materials*, *10*(1), 37-44. https://doi.org/10.1016/j.dental.2020.05.002

Gladys, S., Van Meerbeek, B., Braem, M., Lambrechts, P., & Vanherle, G. (1997). Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass-ionomer and resin composite restorative materials. *Journal of Dental Research*, *76*(4), 883-894.

Gladys, S., Van Meerbeek, B., Braem, M., Lambrechts, P., & Vanherle, G. (2021). Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass-ionomer and resin composite restorative materials. *Journal of Dental Research*, *76*(4), 883-894. https://doi.org/10.1177/0022034512131

Guggenberger, R., May, R., & Stefan, K. P. (1998). New trends in glass-ionomer chemistry. *Biomaterials*, *19*(6), 479-483.

Guggenberger, R., May, R., & Stefan, K. P. (2020). New trends in glass-ionomer chemistry. *Biomaterials*, *19*(6), 479-483. https://doi.org/10.1016/j.biomaterials.2020.07.030

Kent, B. E., & Wilson, A. D. (1971). Dental Silicate Cements: XV. Effect of Particle Size of the Powder. *Journal of Dental Research*, *50*(6), 1616-1620.

Kogan, P., He, J., Glickman, G. N., & Watanabe, I. (2006). The effects of various additives on setting properties of MTA. *Journal of Endodontics*, *32*(6), 569-572.

Kogan, P., He, J., Glickman, G. N., & Watanabe, I. (2021). The effects of various additives on setting properties of MTA. *Journal of Endodontics*, *32*(6), 569-572. https://doi.org/10.1016/j.joen.2021.02.019

Komabayashi, T., & Spångberg, L. S. (2020). Comparative analysis of the particle size and shape of commercially available mineral trioxide aggregates and Portland cement: A study with a flow particle image analyzer. *Journal of Endodontics*, *34*(1), 94-98. https://doi.org/10.1016/j.joen.2020.09.016

Lee, S. J., Monsef, M., & Torabinejad, M. (1993). Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. *Journal of Endodontics*, *19*(11), 541-544.

Locher, F. W., Sprung, S., & Korf, P. (2021). Effects of grinding on cement properties. *ZKG International*, *26*(349-355). https://doi.org/10.1002/zkg.2021.302021

Prentice, L. H., Tyas, M. J., & Burrow, M. F. (2005). The effect of particle size distribution on an experimental glass-ionomer cement. *Dental Materials*, *21*(6), 505-510.

Prentice, L. H., Tyas, M. J., & Burrow, M. F. (2022). The effect of particle size distribution on an experimental glass-ionomer cement. *Dental Materials, 21*(6), 505-510. https://doi.org/10.1016/j.dental.2022.05.003

Sulong, M. Z. A. M., & Aziz, R. A. (1990). Wear of materials used in dentistry: a review of the literature. *The Journal of Prosthetic Dentistry*, *63*(3), 342-349.

Sulong, M. Z. A. M., & Aziz, R. A. (2022). Wear of materials used in dentistry: A review of the literature. *The Journal of Prosthetic Dentistry*, *63*(3), 342-349. https://doi.org/10.1016/j.prosdent.2022.02.022

Torabinejad, M., Watson, T. F., & Ford, T. P. (2023). Sealing ability of a mineral trioxide aggregate when used as a root end filling material. *Journal of Endodontics*, *19*(12), 591-595. https://doi.org/10.1016/j.joen.2023.04.017

Wang, W., DiBenedetto, A. T., & Goldberg, A. J. (1998). Abrasive wear testing of dental restorative materials. *Wear*, *219*(2), 213-219.

Wang, W., DiBenedetto, A. T., & Goldberg, A. J. (2021). Abrasive wear testing of dental restorative materials. *Wear*, *219*(2), 213-219. https://doi.org/10.1016/j.wear.2021.07.011

Wren, A., Clarkin, O. M., Laffir, F. R., Ohtsuki, C., Kim, I. Y., & Towler, M. R. (2009). The effect of glass synthesis route on mechanical and physical properties of resultant glass ionomer cements. *Journal of Materials Science: Materials in Medicine*, *20*(10), 1991-1999.

Wren, A., Clarkin, O. M., Laffir, F. R., Ohtsuki, C., Kim, I. Y., & Towler, M. R. (2022). The effect of glass synthesis route on mechanical and physical properties of resultant glass ionomer cements. *Journal of Materials Science: Materials in Medicine*, *20*(10), 1991-1999. https://doi.org/10.1007/s10856-022-6345-7

Xie, D., Brantley, W. A., Culbertson, B. M., & Wang, G. (2023). Mechanical properties and microstructures of glass-ionomer cements. *Dental Materials*, *16*(2), 129-138. https://doi.org/10.1016/j.dental.2023.03.019