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Effect of blasting media types on Surface Integrity of Commercially Pure Titanium for Implant Applications

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ABSTRACT

This study investigates the effects of different blasting media on the surface properties of titanium as a biomaterial for dental implants. Commercially pure titanium (CP-Ti) samples were treated using three different blasting media (silica, alumina, and glass beads) for 30, 60, and 90 seconds. The surface properties, including surface roughness, microhardness, and wettability, were comprehensively evaluated to assess the impact of these treatments. The results demonstrated that the choice of blasting media and treatment duration significantly influenced the surface characteristics of CP-Ti. Surface roughness and microhardness consistently increased with longer blasting durations across all media types, indicating the potential for enhanced mechanical interlocking and durability. Among the media, silica blasting achieved optimal surface roughness, which is critical for effective osseointegration, making it a suitable option for implants requiring strong bone integration. Conversely, glass-bead blasting exhibited superior enhancement of hydrophilicity, a property essential for promoting cell adhesion and tissue compatibility. These findings underscore the importance of selecting appropriate blasting media and parameters to tailor surface properties for specific clinical applications. The study provides valuable insights into optimizing mechanical surface treatments to improve the performance and longevity of dental and orthopedic implants, thereby advancing the design of biomaterials for medical use.

Keywords: Titanium, blasting, surface, roughness, microhardness, wettability

INTRODUCTION

Commercially pure titanium or CP-Ti has long been the material of choice in biomedical applications, particularly for dental and orthopedic implants, due to its exceptional biocompatibility [1-4]. Its high corrosion resistance further enhances the longevity of medical implants, while its favorable mechanical properties make it ideal for load-bearing applications [5-8]. In addition to these advantages, surface properties play a crucial role in influencing the osseointegration process, which is key to the successful integration of implants with surrounding bone tissue [9]. Surface modification processes can be applied to achieve the required implant surface properties.

Surface modification of biomedical implants, particularly through techniques such as roughening, plays a critical role in determining the materials's interaction with the host tissue [10]. This interaction significantly influences the biological responses at the implant-tissue interface, promoting better integration and reducing the risk of implant failure [11]. Surface roughness, a key parameter in this context, affects the mechanical interlocking between the implant and surrounding bone and cellular behaviors such as attachment, proliferation, and differentiation [12]. An optimized surface roughness enhances osseointegration, a process where the implant surface becomes tightly integrated with the surrounding bone, ensuring long-term stability and functionality [13].

Research indicates that the ideal surface roughness (R_a) is crucial for promoting bone-implant contact and osteoblastic activity. Overly rough implants can cause peri-implantitis, leading to tissue inflammation and bone loss [14,15]. In contrast, overly smooth surfaces may reduce the mechanical interlocking with surrounding tissue. Moderate Ra values within the 1.5 to 3.0 µm range are considered optimal for enhanced osseointegration, as they balance surface area for mechanical interlocking and topographical cues for cellular interaction [16].

Alumina blasting is the most commonly used method to increase surface roughness in various metals, including commercially pure titanium or titanium alloy for biomedical applications [5,11,17-19]. Propelling alumina particles at high velocity onto a substrate effectively creates a textured surface that enhances adhesion and mechanical interlocking. Due to their high abrasiveness, alumina particles efficiently increase surface roughness, which is crucial for improving coating adhesion and promoting osseointegration in dental and orthopedic implants. However, despite its advantages, alumina's sharp edges and embedding tendency can introduce surface defects, potentially compromising surface integrity [17].

On the other hand, silica and glass-bead blasting are less commonly studied than alumina. The comparative analysis of alumina, silica, and glass-bead blasting on CP-Ti surfaces is essential because each method offers unique benefits that can be tailored to different clinical scenarios. Understanding the precise effects of these surface treatments helps optimize implant design and improve patient outcomes, particularly in terms of osseointegration.

MATERIALS AND METHODS

Samples Preparation

To prepare the samples, the CP-Ti plates, with a thickness of 2 mm, were cut into 20 mm × 50 mm dimensions. The chemical composition of CP-Ti is presented in **Table 1**. All samples were pretreated by polishing with abrasive papers to achieve specimens with a uniform surface roughness.

Table 1 Chemical composition of commercially pure titanium

Element	Composition (% by weight)
Ti	Balance
Fe	0.090
C	0.050
N	0.009
H	0.003
O	0.100
Others	<0.4

Surface treatment using the blasting method was conducted on the samples under controlled conditions: blasting times of 30, 60, and 90 seconds, a blasting pressure of 60 bar, and a blasting angle of 90°. Three different types of blasting media were used in this study: alumina (Al_2O_3), silica (SiO_2), and glass beads. All blasting media were prepared in 50-mesh size. In addition, the blasting media were imaged using an Olympus SZX16 digital microscope and measured with ImageJ software to confirm particle size.

Roughness Measurement

Arithmetic mean roughness or roughness average (R_a) quantifies the average deviation from the mean line across the surface [10], giving a general roughness level and expressed as µm [20]. The following equation obtains Ra:

$$R_a = \frac{1}{L}\int_0^L |Y(x)|dx \quad (1)$$

where L is the evaluation length, and Y is the ordinate of the profile curve. The R_a values for all CP-Ti samples were measured and calculated using the Mitutoyo SJ-210 (Japan) surface tester device. This study used a standard drive unit for measurements following the ISO 1997 R standard, featuring a measuring force of 4 mN, a diamond stylus with a 5µm tip radius, and a conical-taper angle of 90° [21]. The measurement was performed over a length of 4.8 mm at a speed of 0.25 mm/s. Roughness measurements were conducted five times for each sample. The average of all surface roughness values was considered. Additionally, this device generated line profiles to obtain distinct surface roughness characteristics for each sample. The surface line profile graph was processed using OriginPro 2024 graphing and analysis software.

Microhardness Test

Hardness measurements were conducted to assess changes in the sample's hardness after the blasting processes. The Vickers hardness test involved pressing a diamond indenter, shaped like a square pyramid with a 136° angle, perpendicularly onto the specimen's surface [22]. The Vickers microhardness values were obtained using a 500 gf load applied for 15 seconds of dwell time [23,24], measured with a BUEHLER high-quality microhardness tester. The Vickers hardness number (HV) is calculated according to the ASTM E384-22 standard using the following formula:

$$HV = 1854.4 \times \frac{P}{d^2} \quad (2)$$

where P is force (gf), and d is the mean diagonal length of the indentation (µm). Each sample was evaluated for surface hardness at ten random points.

Wettability Inspection

After roughness characterization and microhardness testing, the wettability of the blasted CP-Ti samples was assessed. Wettability, which reflects the surface's affinity for liquids, is a crucial factor influencing cell adhesion and protein adsorption on biomaterial surfaces [25]. The sessile drop method was employed to measure the water contact angle (WCA) [26]. To evaluate this property, contact angle measurements were performed using an Ossila contact angle goniometer. A 5 µl droplet of distilled water was carefully placed on each blasted surface [27]. The static contact angle was measured at room temperature after 5 seconds [28]. The 5-second interval allows the droplet to stabilize, ensuring accurate measurements. The water contact angle for each sample was determined by averaging five measurements. The measured contact angle value can indicate the hydrophilicity of the material's surface [19,29].

RESULTS AND DISCUSSION

Fig. 1 presents the images and average particle size of all blasting media based on macroscopic observations. Alumina and silica particles have similar irregular and non-uniform shapes, whereas glass beads are more uniform and spherical (**Fig. 1 a-c**). According to measurements from ImageJ software, the average particle sizes of alumina, silica, and glass beads are 355.453 µm, 337.936 µm, and 302.187 µm, respectively (**Fig. 1d**).

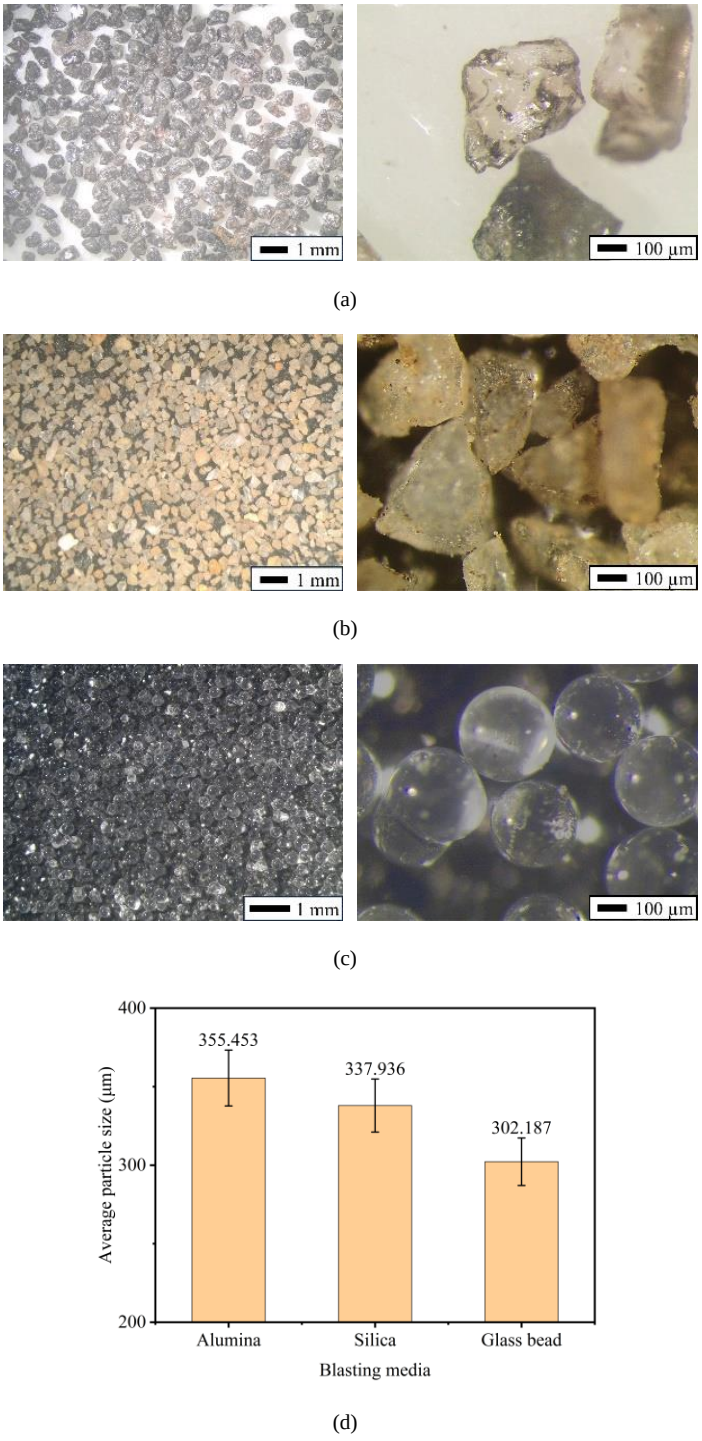

Fig. 1 Photographic images of blasting particles: (a) alumina, (b) silica, (c) glass beads, and (d) average particle size.

Surface Roughness

The roughness characteristics are shown by the peaks and valleys in the line profile, as illustrated in **Fig. 2**. The line profile shows that alumina blasting produced the roughest surface, compared to silica and glass-bead blasting, with glass-bead blasting resulting in the smoothest surface.

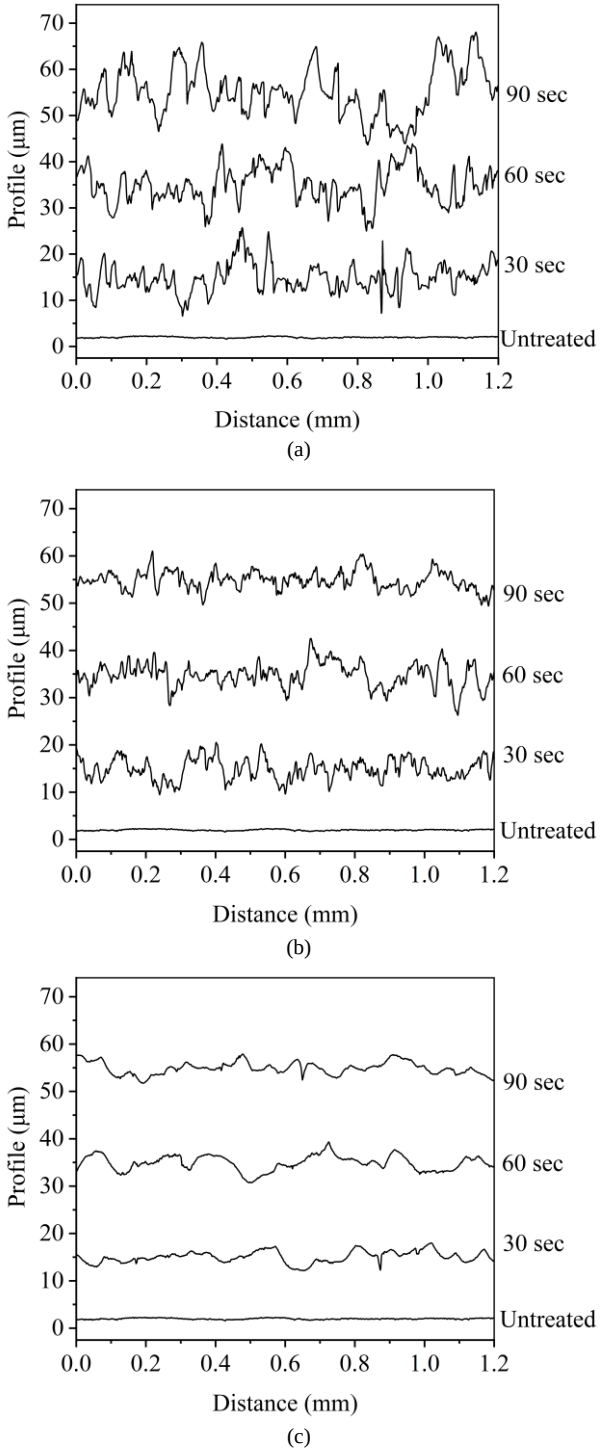

Fig. 2 Line profiles of the surface's roughness: (a) alumina blasted, (b) silica blasted, (c) glass-bead blasted.

As illustrated by the line profile, the arithmetic mean value (roughness average, R_a) of the surface can be calculated using Equation 1, with results displayed in **Fig. 3**. Among the blasting media, alumina blasting produces the highest R_a value, followed by silica blasting, while glass-bead blasting yields the lowest R_a value. The primary reason for the high R_a value in alumina blasting on the CP-Ti surface is the pronounced peak heights and valley depths.

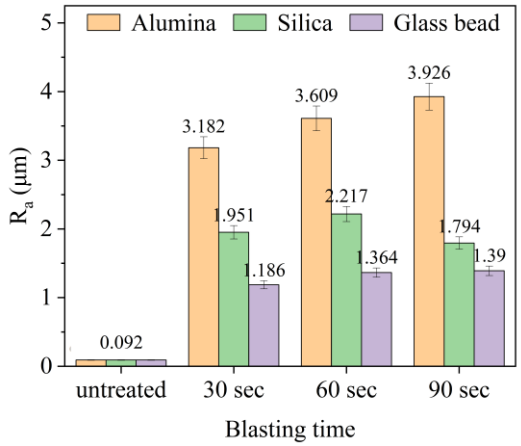

Fig. 3 Surface roughness of CP-Ti after blasting treatment.

Surface roughness profiles varied notably with particle size of blasting media, as both peak heights and valley depths increased with larger particle sizes [17]. Small particle sizes created uniformly spaced, shallow pits across the blasted surface, whereas larger particle sizes formed deeper and wider microcraters and valleys. Additionally, physical properties such as the shape and morphology of the blasting media significantly impact surface roughness, as reported in the literature [23]. Furthermore, the average surface roughness increases with longer blasting times, particularly with alumina, while glass-bead blasting results in the smoothest surfaces.

In silica blasting, the surface roughness did not increase significantly compared to other media due to silica particles' relatively lower hardness and abrasiveness. Unlike alumina, silica particles may cause less aggressive surface deformation, resulting in a more uniform and moderate texture. Additionally, silica blasting may lead to smoother surfaces as the particles are less likely to create deep grooves or rough profiles, which limits the overall increase in roughness even with extended blasting durations. This makes silica blasting more suitable for applications requiring smoother, less aggressive surface modification.

The image in **Fig. 4** provides a cross-sectional view of CP-Ti before and after silica blasting for 30, 60, and 90 seconds. The untreated sample exhibits a relatively smooth surface with no visible alterations. However, as the blasting duration increases, distinct surface modifications become evident. At 30 seconds of silica blasting, initial roughening is observed, with localized changes in surface topography starting form. By 60 seconds, significant modifications are apparent, including the formation of pronounced valleys, as indicated by the red-circled regions in the image. These valleys result from the increased impact of abrasive particles, creating deeper indentations in the titanium surface. After 90 seconds of blasting, the surface exhibits a more homogenized rough texture, suggesting that the cumulative effects of prolonged blasting lead to more uniform deformation.

The formation of extreme valleys, particularly in 60 seconds, may have implications for the mechanical and biological performance of the titanium surface. While enhanced roughness can improve osseointegration by providing better anchorage for bone tissue, excessively deep valleys could compromise mechanical stability or increase the risk of stress concentrations. These observations highlight the importance of optimizing blasting parameters to achieve the desired balance between surface roughness and structural integrity for biomedical applications.

Microhardness Result

Mechanical surface treatments, such as alumina, silica, and glass-bead blasting, not only produced surface roughness but also affected the surface microhardness and wettability of the material [18,19]. **Fig. 5** and **6** display the values of Vickers microhardness and water contact angle (WCA) of surface-treated CP-Ti, respectively. The WCA is a measurement method used to analyze the hydrophilicity of surface material.

Microhardness measurements were conducted on randomly selected surface areas before and after each blasting treatment on CP-Ti surfaces. Before treatment, a microhardness of 202.13 HV was recorded, consistent with values reported in prior

studies [7,24]. All microhardness values significantly increased with extended blasting times (**Fig. 5**). The increased microhardness can be attributed to work hardening, which leads to a fine-grained structure and residual stress within the thin surface layer after impact from the blasting media [23].

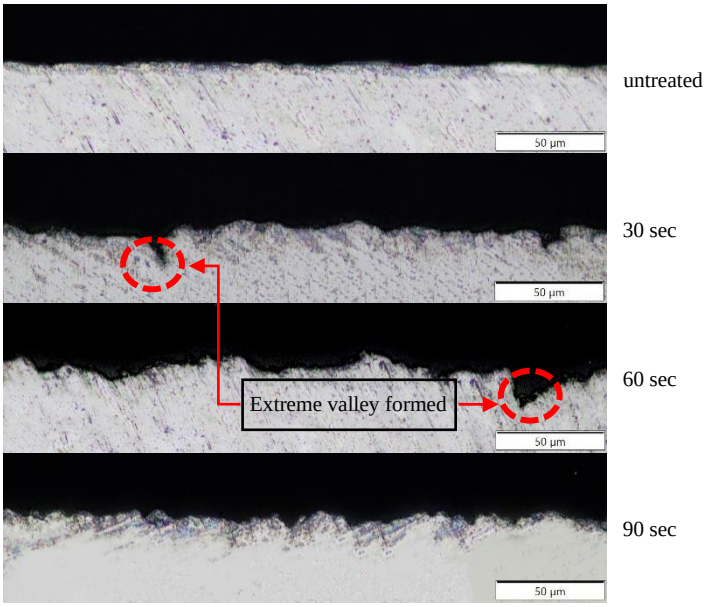

Fig. 4 Cross-sectional view of CP-Ti before silica blasting and after treatment durations of 30, 60, and 90 seconds.

Wettability Condition

Wettability was measured using the water contact angle. Still, results varied across blasting treatments (**Fig. 6**). The wettability of most titanium surfaces remains relatively constant, typically exhibiting water contact angles ranging from 60° to 120° [30]. Glass-bead blasting, which produced the smoothest roughness surface than alumina and silica blasting (**Fig. 2 c**), resulted in a lower contact angle, making it more hydrophilic compared to other blasting treatments (**Fig. 6**). This increased hydrophilicity can enhance cell attachment and bioactivity, which are beneficial for osseointegration in implant applications [30]. A study found that hydrophilic surface treatment of CP-Ti disks influences osteogenic cell adhesion and differentiation, which might enhance osseointegration [31].

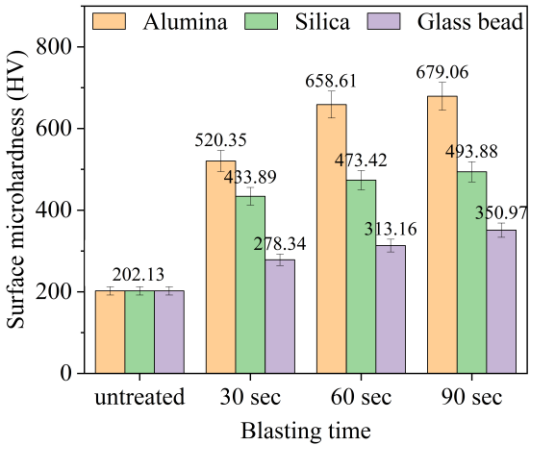

Fig. 5 Values of the Vickers microhardness on the surface of CP-Ti.

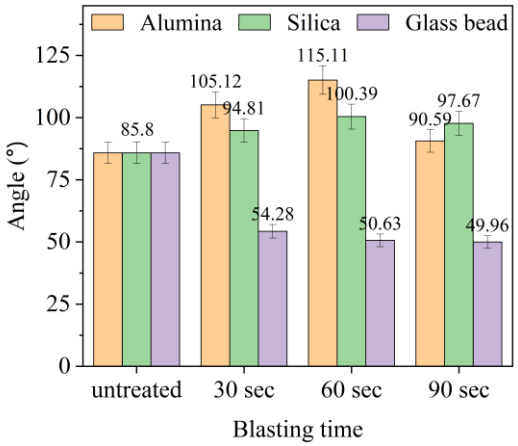

Fig. 6 Contact angle measurement of CP-Ti blasted.

Discussion

The study's findings indicate that, except for silica blasting, surface roughness and microhardness increased proportionally with longer blasting durations across all media types, emphasizing the significant role of blasting time in tailoring surface properties. However, due to silica's lower hardness and abrasiveness, surface roughness showed no significant increase beyond 60 seconds in the case of silica blasting. These results align with existing literature highlighting abrasive media characteristics' influence on surface modification outcomes [32,33]. The hardness and shape of abrasive particles are key factors affecting treated materials' surface roughness and hardness [17,32]. Harder abrasives, such as alumina and steel grit, create more pronounced surface profiles and enhance microhardness more effectively than softer media like silica sand. This is because harder abrasives transfer greater kinetic energy upon impact, leading to increased plastic deformation of the substrate surface [34].

Furthermore, blasting duration is crucial in determining surface characteristics [35]. Extended blasting times increase impacts per unit area, increasing surface roughness and work hardening. However, this effect plateaus beyond a certain threshold, as observed with silica blasting. Due to silica particles' limited abrasiveness and lower hardness, prolonged exposure does not significantly alter the surface after an initial period.

The choice of abrasive media and blasting parameters must be carefully tailored to the specific material and desired surface characteristics [36]. For example, in applications involving medical-grade 316L stainless steel, studies have shown that using spherical metallic shot results in distinct surface morphologies and microhardness distributions compared to angular silica particles [23].

In orthopedic and dental implants, surface roughness is critical because it enhances osseointegration, or the stable integration between the implant and surrounding tissue [9]. A textured implant surface improves cell adhesion and promotes mechanical interlocking, essential for long-term stability. Moreover, a rough surface increases the implant surface area, facilitating greater protein absorption and stronger cellular interactions, further enhancing osseointegration. Research showed that micro- and nano-scale surface modifications significantly improved the primary stability of implants by supporting tissue regeneration and reducing the risk of implant rejection and infection [3,11].

The ideal surface roughness for optimal osseointegration ranges from 1,5 to 3 µm [16], with a roughness close to 2 µm being particularly suitable, as indicated in the literature based on bone-to-implant contact [37]. In this work, silica blasting at various durations achieved this effective roughness, enhancing the potential for osseointegration. Additionally, silica blasting has been found to increase the surface hardness of samples by approximately 500 HV (**Fig. 5**). High hardness is beneficial as it helps minimize the wear process, a mechanical phenomenon caused by friction between the implant and bone tissue, which can result in the release debris at the implant site [24]. On the other hand, glass-bead blasting formed a more hydrophilic surface than other treatments, which could be advantageous for implant applications by promoting cell adhesion. These findings offer important insight into the selection of blasting media, suggesting that each media type can be

tailored to achieve specific surface properties that promote optimal osseointegration.
In conclusion, the study reinforces existing research on the critical relationship between abrasive media characteristics, blasting duration, and resulting surface properties. Understanding these interactions is essential for optimizing surface treatment processes to achieve specific performance objectives.

CONCLUSIONS

This study demonstrates that blasting media produces distinct surface characteristics on commercially pure titanium (CP-Ti). Except for silica blasting, surface roughness and microhardness increased proportionally with longer blasting durations across all media types, highlighting the significant role of blasting time in tailoring surface properties. However, in the case of silica blasting, surface roughness showed no significant increase beyond 60 seconds due to silica's lower hardness and abrasiveness. Among the media tested, silica blasting achieved the optimum surface roughness required for effective osseointegration, making it a promising choice for applications where strong integration with biological tissues is critical. On the other hand, glass-bead blasting demonstrated superior hydrophilicity, which could enhance biological fluid interactions and promote cell attachment.
These observations underline the importance of selecting the appropriate blasting media and parameters to achieve specific surface modifications tailored to the desired application. The ability to optimize surface characteristics through controlled mechanical treatments provides a valuable tool for improving the performance and longevity of orthopedic and dental implants. By understanding the distinct effects of different blasting media, clinicians and manufacturers can make informed decisions to enhance implant integration, functionality, and patient outcomes. This study contributes to the growing knowledge base required to design next-generation biomaterials with customized surface properties for advanced medical applications.
Given this study's limitations, further research should focus on evaluating the corrosion resistance of the treated titanium surfaces to ensure long-term durability, especially in biomedical applications.

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REFERENCES

1. A.M. Mathew, P.V. Sreya, K. Venkatesan, A. Ganesan, D.K. Pattanayak: ACS Applied Bio Materials, 6(6), 2023, 2284–2294. https://doi.org/10.1021/acsabm.3c00163
2. A. Stricker et al.: Dental Materials, 38(8), 2022, 1395–1403. https://doi.org/10.1016/j.dental.2022.06.028
3. I.D.S. Brum, C.N. Elias, J.C.A. Lopes, L. Frigo, P.G.P.D. Santos, J.J.D. Carvalho: Coatings, 14(8), 2024, 951. https://doi.org/10.3390/coatings14080951
4. B. T. Prayoga, S. Suyitno, R. Dharmastiti: Acta Metallurgica Slovaca, 24(1), 2018, 65. https://doi.org/10.36547/ams.24.1.255
5. R. Granato et al.: Journal of the Mechanical Behavior of Biomedical Materials, 97, 2019, 288–295. https://doi.org/10.1016/j.jmbbm.2019.05.026
6. S. Safaee et al.: Dental Materials Journal, 40(4), 2021, 949–956. https://doi.org/10.4012/dmj.2020-323
7. M. Shirooyeh, J. Xu, T.G. Langdon: Materials Science and Engineering: A, 614, 2014, 223–231. https://doi.org/10.1016/j.msea.2014.07.030
8. M. Echeverry-Rendón et al.: Journal of Materials Science: Materials in Medicine, 26(2), 2015, 72. https://doi.org/10.1007/s10856-015-5408-4
9. M. Hasegawa et al.: International Journal of Molecular Sciences, 21(3), 2020, 783. https://doi.org/10.3390/ijms21030783
10. A. I. Nicolas-Silvente, E. Velasco-Ortega, I. Ortiz-Garcia, L. Monsalve-Guil, J. Gil, A. Jimenez-Guerra: Materials, 13(2), 2020, 314. https://doi.org/10.3390/ma13020314
11. M. Zboun, V. Arısan, N. Topcuoglu, F. Kuruoglu, L.T. Sener, F. Sarcan: Surfaces and Interfaces, 21, 2020, 100703. https://doi.org/10.1016/j.surfin.2020.100703
12. Y. Zhang, Z. Fan, Y. Xing, S. Jia, Z. Mo, H. Gong: Frontiers in Bioengineering and Biotechnology, 10, 2022, 981062. https://doi.org/10.3389/fbioe.2022.981062
13. G. R. M. Matos: Journal of Maxillofacial and Oral Surgery, 20(1), 2021, 1–4. https://doi.org/10.1007/s12663-020-01437-5
14. A. Dank, I. H. A. Aartman, D. Wismeijer, A. Tahmaseb: International Journal of Implant Dentistry, 5(1), 2019, 12, https://doi.org/10.1186/s40729-019-0156-8
15. N. Saulacic B. Schaller: Journal of Oral and Maxillofacial Research, 10(1), 2019. https://doi.org/10.5037/jomr.2019.10101
16. E. Velasco-Ortega et al.: International Journal of Molecular Sciences, 22(16), 2021, 8507. https://doi.org/10.3390/ijms22168507
17. O. Yetik, H. Koçoğlu, Y.Y. Avcu, E. Avcu, T. Sinmazçelik: Materials Today: Proceedings. 32, 2020, 27–36. https://doi.org/10.1016/j.matpr.2020.05.512
18. A. Yabe, M. Okada, E.S. Hara, Y. Torii, T. Matsumoto: Colloids and Surfaces B: Biointerfaces, 211, 2022, 112283. https://doi.org/10.1016/j.colsurfb.2021.112283
19. A.C. Cura, J.I. Zuchuat, L.T. Tribbia, I.R.E. Taravini, O.A. Decco: Materialia, 21, 2022, 101302. https://doi.org/10.1016/j.mtla.2021.101302
20. V. Traver-Méndez et al.: Materials, 16(17), 2023, 6012. https://doi.org/10.3390/ma16176012
21. M. K. Gupta, P. K. Sood: Friction, 5(2), 2017, 155–170. https://doi.org/10.1007/s40544-017-0141-2
22. J. Sawangpan, S. Panich, T. Jantarasricha, A. Khantachawana: Journal of Metals, Materials and Minerals, 33(1), 2023, 56–64. https://doi.org/10.55713/jmmm.v33i1.1594
23. B. Arifvianto, M. Mahardika, U.A. Salim, S. Suyitno: Journal of Engineering and Technological Sciences, 52(1), 2020, 1–13. https://doi.org/10.5614/j.eng.technol.sci.2020.52.1.1
24. M. Rossi, P. Kuroda, M.R. Danelon, L.S. Rossino, C.R.M. Afonso: Materials Letters, 370, 2024, 136773. https://doi.org/10.1016/j.matlet.2024.136773
25. G. D. S. D. Lucca et al.: Materials Research, 24, 4, 2021, e20210102. https://doi.org/10.1590/1980-5373-mr-2021-0102
26. R. Zhang, T. Yang, S. Liu, H. Wu, J. Long, L. Xie: Materials Chemistry and Physics, 293, 2023, 126893. https://doi.org/10.1016/j.matchemphys.2022.126893
27. R. B. W. Lima, S. C. Barreto, N. M. Alfrisany, T. S. Porto, G. M. De Souza, M. F. De Goes: Dental Materials, 35, 11, 2019, 1557–1567. https://doi.org/10.1016/j.dental.2019.07.008
28. H. Pratiwi, Kusmono, M. W. Wildan: Journal of Materials Research and Technology, 30, 2024, 8648–8660. https://doi.org/10.1016/j.jmrt.2024.05.233
29. M. Walkowicz, E. Rudnik, P. Osuch, D. Pęczar: Metalurgija, 64(1-2), 2025, 45–48. https://hrcak.srce.hr/clanak/462237
30. D. Kido et al.: International Journal of Molecular Sciences, 24, 19, 2023, 14688. https://doi.org/10.3390/ijms241914688
31. M. A. F. Martinez et al.: International Journal of Implant Dentistry, 6, 1, 2020, 46. https://doi.org/10.1186/s40729-020-00243-5
32. D. Draganovská, G. Ižaríková, A. Guzanová, J. Brezinová: Metals, 8, 11, 2018, 938. https://doi.org/10.3390/met8110938
33. Y. Liu et al.: Micromachines, 15, 12, 2024, 1405. https://doi.org/10.3390/mi15121405
34. H. V. Özkavak: Journal of Materials Engineering and Performance, 34, 2, 2025, 916–933. https://doi.org/10.1007/s11665-023-09110-x
35. M. Gadge, G. Lohar, S. Chinchanikar: Materials Today: Proceedings, 64, 2022, 725–730. https://doi.org/10.1016/j.matpr.2022.05.196
36. V. K. S. Hsiao, M.-H. Shih, H.-C. Wu, T.-I. Wu: Applied Sciences, 14, 23, 2024, 10904. https://doi.org/10.3390/app142310904

37. E. Anbarzadeh, B. Mohammadi: Journal of Bionic Engineering, 21, 1, 2024, 303–324. https://doi.org/10.1007/s42235-023-00422-1