



PURPOSE

To present available additive-manufactured ceramics, their physical and mechanical properties, and the technologies involved in additive manufacturing of dental ceramics.

METHODOLOGY

An electronic Google search of the English language was made to explore 3D-printed ceramic materials and related technology in Dentistry. In addition, literature from 2013 to September 2024 was performed using PubMed with key terms including 3D-printed ceramics, zirconia, lithium disilicate, translucency, fluorescence, esthetic performance, mechanical property, physical property, wear, fracture strength, and flexural strength using Boolean operators ‘AND/OR.’ To meet the review's objectives, inclusion and exclusion criteria were set out, and a final list of articles was comprehensively reviewed. The esthetic performance was evaluated through studying translucency and fluorescence properties of lithium disilicate crowns. This evaluation included both laboratory and clinical studies comparing 3D-printed and conventionally fabricated lithium disilicate crowns.

RESULTS

The literature search revealed a total of 130 articles. After duplicate removal, 116 articles remained. The titles/abstracts of these articles were screened based on selection criteria. Twenty articles were found to be pertinent, and their full texts were retrieved and critically appraised.

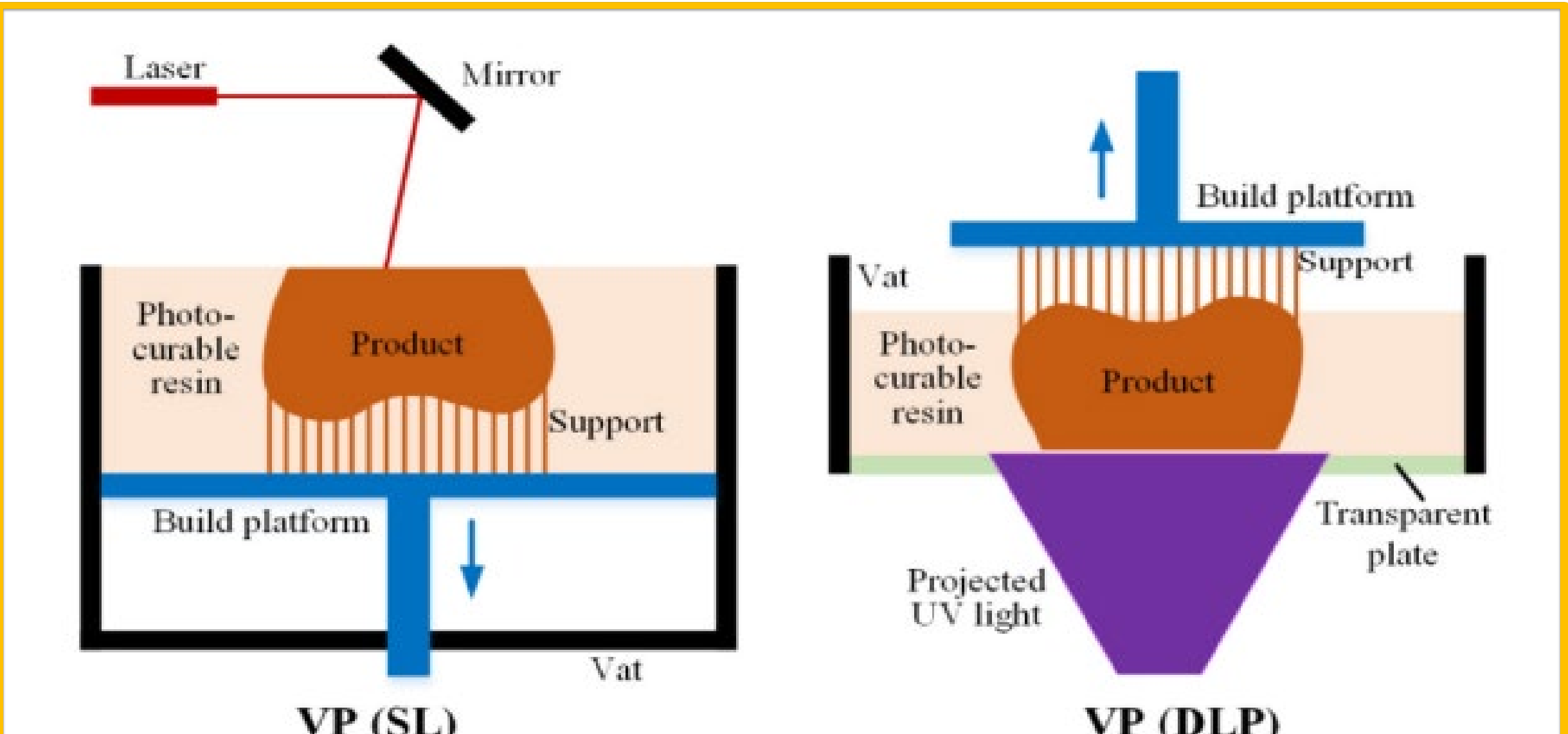


Fig 1: Additive manufacturing (AM) technologies

3D Technology	Advantages	Disadvantages
Stereolithography (SLA)	Quick production speed; Precise and highly accurate; Can accommodate complex designs; Numerous material options.	Production can be slower compared to other printers; High post-processing requirements.
Digital light processing (DLP)	High speed; Precise and highly accurate; Can accommodate complex designs; Numerous material options.	Arguably lower quality than other printers; Limited by voxel size.
Fused deposition modeling (FDM)	Cheaper technology; Great layer bonding.	Only thermoplastic materials.
Selective laser sintering (SLS) and SLM	Can print polymers or metals; Batch production; No supports needed.	Requires high printing infrastructure; Use of fine powders can be hazardous.

Table 1: Advantages & Disadvantages of AM technologies

Author (Year)	Method	Printing Technology	Key Findings
Al Hamad KQ et al. 2022	Systematic review & meta-analysis; 28 studies (2015-2021)	SLA DLP Self-Glazed Zirconia	- SM had higher flexural strength, fracture toughness, and better overall accuracy- especially in marginal and occlusal areas. - AM had advantages in elastic modulus, wettability, and detail reproduction in complex geometries.
Valenti et al. 2024	Systematic review & meta-analysis; 76 studies (2016-2021)	SLA DLP Stereolithographic ceramic manufacturing (LCM)	- AM shows comparable marginal discrepancies, but lower flexural strength, hardness, and fracture load compared to milled and conventional techniques. - Milling shows better results for flexural strength, especially after aging. - No significant difference in terms of fit accuracy and roughness between AM and milling.
Balestra D et al 2024	Systematic review of literature; 83 studies (2013-2023)	SLA DLP LCM	- AM zirconia demonstrated good mechanical properties, though lower flexural strength than conventionally milled zirconia. - Biocompatibility and fracture resistance suitable for clinical applications in posterior restorations. - Key challenges included porosity and surface roughness. - Factors like build angle and printing orientation significantly influence the final material properties. 3D-printed lithium disilicate resulted with good translucency and color stability, making it ideal for anterior restorations.
Dewan H et al. 2023	Systematic review & meta-analysis; 9 articles for quantitative analysis (2004-2022).	SLA LCM	- Milled crowns performed better clinical survival rate and marginal integrity. - No significant correlation between cement type and survival rate. - Trueness and accuracy were comparable between milled and 3D-printed zirconia crowns.
W. Frąckiewicz et al. 2024	Systematic review & meta-analysis; 19 studies.	SLA DLP LCM	3D printed zirconia exhibits lower flexural strength compared to milled zirconia, but results are not statistically significant. - Microhardness between the two techniques shows no significant difference. - High heterogeneity in the studies affects the consistency of results.
M.A. Alghauli et al. 2024	Systematic review and meta-analysis; 2 clinical trials and 36 laboratory studies (2013-2023)	SLA DLP SLM LCM	- Milled zirconia showed higher flexural strength in thinner specimens (≤ 1.5 mm) than 3D-printed zirconia, but thicker specimens showed comparable results. - Fracture resistance was influenced by aging, restoration type, and thickness. - Veneering ceramic bond strength was comparable between both methods.
Su et al. 2023	A critical review of existing literature	SLA DLP LCM	3D printed zirconia exhibits lower flexural strength compared to milled zirconia but meets ISO standards. - Biocompatibility and accuracy show promise for clinical use, especially in implants and scaffolds - Surface roughness, porosity, and interlayer defects pose challenges for long-term use. - Aging impacts the phase transformation of zirconia, affecting mechanical stability.

Table 2: Narrative Review

DISCUSSION

The collective analysis of 3D-printed zirconia and lithium disilicate across the discussed papers emphasizes their potential in dentistry while recognizing existing challenges. Zirconia is praised for its mechanical strength and biocompatibility, ideal for crowns and implants, though issues like porosity and surface roughness from 3D printing affect accuracy and durability. Lithium disilicate, known for its aesthetic qualities, is favored for anterior restorations but has lower strength, limiting its use in high-load areas. Both materials benefit from 3D printing's customization capabilities, yet improvements in interlayer bonding, shrinkage control, and surface finishing are crucial for better clinical outcomes. Overall, further clinical trials and standardization of 3D printing processes are needed to optimize their long-term reliability

CONCLUSIONS

3D printing in dentistry holds great potential, offering significant advancements in personalization and innovation for dental restorations. However, the standardization of manufacturing processes and more clinical trials are essential to optimize material performance and ensure long-term success in clinical settings. Improving production techniques, enhancing accuracy, and conducting rigorous clinical studies will be critical in fully realizing the benefits of 3D printing.

REFERENCES

