Original Article

Design And Digital Fabrication Technique of a Hybrid Framework - A Literature Review

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Abstract

Hybrid dentures consist of one of the most popular options in the fixed restoration of the edentulous arch. For a successful and durable prosthesis it is of utmost importance to pay good attention to the design and fabrication of such implant frameworks. Conventionally the framework was fabricated using traditional metal casting. However, with the advent of digital dentistry CAD CAM frameworks have become popular and their fabrication much easier and efficient.With a focus on design of implant frameworks and the digital fabrication process of hybrid dentures, the goal of this study was to summarise the pertinent literature in this area.In conclusion, hybrid dentures seem like a viable treatment option when designed correctly and CAD CAM technique seems like a popular and efficient technique to do so.

Keywords: Hybrid Denture, Framework, Dmls, Milling, 3-Shape, Digital Dentistry

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INTRODUCTION

Traditionally Hybrid frameworks were constructed using metal and traditionally manufactured using conventional casting (lost wax). However with the advent of digital dentistry many techniques and materials have been introduced into the world of fixed prosthodontics. There have been many studies comparing the accuracy of metal prosthesis fabricated using different manufacturing techniques (1). Most of the studies suggested the additive technique (DMLS) to be the most accurate in terms of marginal and internal accuracy(2).

CAM milling technology is very often referred to as a subtractive process. In layman terms it involves taking a block of material and cutting away everything that is not necessary until the final restoration is procured. This is in contrast to the additive processes which involve addition of material layer by layer to build the final product. In a study done by Eun-Jeong et al, where they compared overall accuracy of dental restorations fabricated using additive and subtractive techniques, additive techniques fared better(3)(4).

Various additive techniques used to fabricate metal prosthesis are Stereolithography, Digital Light Processing (DLP), Direct metal laser sintering. Direct metal laser sintering has more applications in the dental field as compared to the other 2 methods. Direct metal laser sintering (DMLS) was developed jointly by Rapid Product Innovations (RPI) and EOS (Electro Optical System Germany), starting in 1994, because of the first commercial rapid prototyping.

This review looks into the design considerations and digital techniques of fabricating implant frameworks.

Design Considerations

Implant frameworks must be rigid to support a fixed prosthesis. Cantilevered segments in the areas of high stress could lead to compromise in the integrity of the framework and could eventually lead to framework fracture. Hence the significance of AP spread.

Ap Spread And Cantilever Extension

Cantilever extensions have been utilised in dentistry to varied degrees, but their use has been discouraged due to its impact on the abutment (5). However, in the case of implant-supported prosthesis, cantilever extensions are used to restore the lost occlusion(6). The A/P spread is an important aspect in the distribution of occlusal loads because it offers a macroscopic measure of the geometric distribution of the implants(7). While Rangert recommended a minimum of 10mm cantilever length, English recommended limiting the cantilever extension to 1.5 times the A/P spread when five implants were present (7,8). English also stressed on the ill effects of vertical cantilever when the crown:implant ratio exceeded 2:1(9).

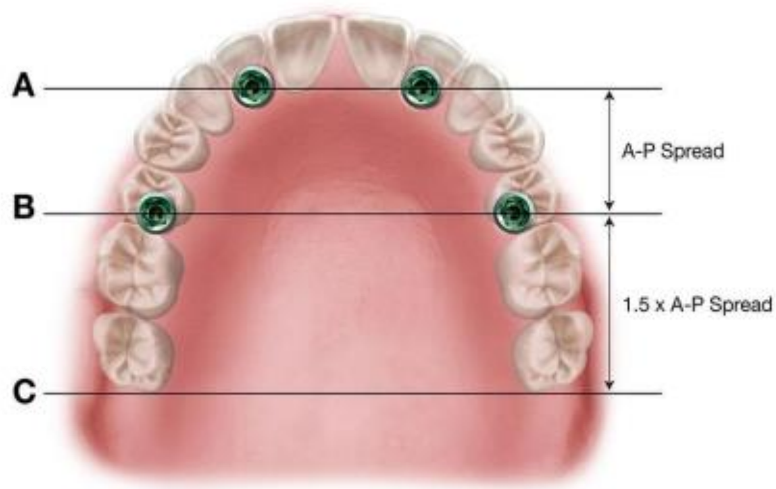

Fig1 : AP Spread and Cantilever extension (Courtesy: Glidewell dental)

Multiple authors recommended modifying the framework to lessen the stress induced by the cantilever extension. For support, Worthington et al and Sones et al recommended integrating enough metal distal to the posterior abutment as well as around the cylinders(10).

To counterbalance the stresses, Taylor and Bergman recommended a minimum of 5.4 mm occluso gingival thickness and 4.2 mm facio-lingual thickness (10,11). For improved stress distribution, Jemt advocated a minimum thickness of 4-6mm occluso gingivally, and Ramussen suggested using an I-beam design(12)(13).

Design Of The Framework

The design of the framework plays a major role in the success of the prosthesis. The design depends upon the geometry and characteristics of the material used(13,14).

The frameworks must maintain a minimum thickness; Taylor proposed that the frameworks be 3mm thick(15), while Carr and Stewart advocated that cast bars be around 7 mm tall and 6 mm wide(16).

Thickness of the framework primarily depends on the type of metal, fabrication technique used for each specific framework, the number and length of implants, the type of supporting bone, and the opposing occlusion. Various designs such as ‘I’, ‘L’, ‘U’, ‘oval’, ‘elliptical’, ‘square’ have been widely used and extensively tested for efficiency in clinical and lab settings. Designs with ‘I’ and ‘L’ shapes are great clinical options with ‘I’- shaped bars having the highest resistance at the region of the cantilever(17,18).

I' beam also provides increased rigidity and strength to the framework with minimal increased bulk and weight. Rasmussen stated that I-beam-designed frameworks maximised resistance to occlusal loading and minimised permanent deformation under stress(13). Staab and Stewart measured beam deflection and maximum normal stress in 'L', 'I', 'elliptical' and 'oval framework designs and found that I-beam design deflected less and experienced the smallest maximum normal stress of the tested designs, while L design experienced the largest normal stress(19). Mericske-Stern recommended the 'U'-type because of a larger transversal area to promote better bonding at welding(20)(11). De Carvalho tested the resistance to compression of the 'T' bar, inverted 'T' bar and rectangular bar and showed that the most resistant design was the rectangular bar(11,21). It was stated by Von Gonten et al that relative to the design of the framework, consideration should also be given to limit the amount of acrylic resin required to retain artificial denture teeth. He described a design that consisted of an L-beam with extended vertical wall height lingualy(22). But there wasn't any scientific evidence to prove the clinical success.

Fig 2 : CAD/CAM framework designed using an I-bar design.Facial and lingual surface were modified similar to the L-beam design to better attach to the acrylic. (Courtesy : Drago et al 2013

Site

Difference in the resorptive patterns between the maxillary and mandibular arches usually leads to difficulty in implant placement in the ideal positions, complicating the prosthetic relation between the arches(22,23)(24). The esthetic demands in the maxillary prosthesis tend to be more dramatic when compared to the mandibular prosthesis. As per Zarb and Schmit, unlike mandibular implant prostheses where hygienic type designs have proven to be functionally and aesthetically acceptable, maxillary implant prosthesis comes with an array of different esthetic and functional requirements(25). Maxillary prosthesis is expected to predictably restore original soft tissue contours, tooth positions, and arch forms. It also has a great impact on speech, and patients have also identified speech as a major factor in perceived satisfaction of their prostheses(26).

Passivity Of The Framework

Importance of passivity: Osseointegrated implants are subjected to static and dynamic loading. Dynamic forces on the implants may arise due to chewing which can reach various magnitudes(26,27) whereas tension in the bridge locking screws, when securing a misfitting framework to the implants induces a static force(12,28).Passive fit or a strain free superstructure is theorised to exert zero strain on the supporting implants in the absence of an external load. However, fabricating an absolutely passive framework with the available technologies is considered to be impossible(29). Branemark stressed that a controlled mechanical environment is necessary to assure adequate remodelling stimulus for maintenance of osseointegration(30). Milled frameworks from solid blanks of Ti or Ti alloys are homogeneous; with minimal defects when compared to defects noted within cast frameworks(31). CAD CAM fabricated frameworks generally provide better, more accurate fit than conventional cast framework(32).

Influence Of The Prosthesis Type And Effect On Force Distribution Around The Implants: Weight

There is a general belief that the lighter materials are advantageous owing to their weight but they lack substantial research in this aspect in implant dentistry. This is followed by the use of titanium with coated acrylic resin, weighing 15-18g(33). This use of milled titanium was encouraged to avoid the difficulties associated with casting titanium and can optimise the results(34). Another option would be the use of the CoCr framework. CoCr framework with acrylic teeth weighed around 20g while ceramic layering weighed a whopping 60g almost 55% higher than a layered titanium prosthesis(35). However Bhering et al who evaluated the strain around the implants with a CoCr superstructure found it to be better than titanium(36). There is hence a direct relationship between the weight, material used and the strain generated around the implants.

Number Of Implants

When observing the relation between the strain on the implant and the number of implants used, it was observed that with the increase in the number of implants the strain decreased. This relationship however is not linear, since twice as many implants does not generate half as much force. This could be owing to the varying anatomy of bone, and the distribution of implants(37).

Fit Of The Prosthesis

The passivity of the framework is fundamental to the success of the prosthesis and also for the underlying implants(37,38). Any misfit, clinically discernable or not is believed to induce internal stresses in the framework as well as the surrounding bone(28,37). Passivity of fit in terms of screw retained prosthesis is difficult to achieve especially in the case of multi-unit implant supported prosthesis(39). Jemt and Lekholm were pioneers in assessing the relation between deformation of the framework and underlying bone due to the misfit of the framework. In an animal study which involved the placement of implants in the tibia of rabbit, they found that a deformation of upto 100µm was caused at the bone level when the prosthetic discrepancy was in the range of 50µm. They highlighted the role of this deformation in the initial phase of osseointegration(39,40). Arturo Natali et al assessed the stress induced in the peri-implant bone in association with labio-lingual and mesio-distal misfit(41). They were able to conclude that the compressive stress peak in the mesio-distal direction was 50% greater than that in labiolingual direction. They also stressed the importance of the stiffness of the framework, and suggested the use of framework material with low stiffness for better peri-implant response. Contrary to these observations, a recent systematic review by Katsoulis et al considered that there was insufficient evidence on the influence of prosthetic misfit on clinical outcomes in terms of screw-retained prosthesis(42).

Digitally Designing The Framework

The cast can be scanned using the Medit Lab scanner (Medit T500). Lab scanners can be used as they have shown superior trueness and precision in comparison to intraoral scanners(Mangano et al., 2016; Dutton et al., 2020). This scan can be used to design a Non- Engaging implant supported hybrid denture framework using digital softwares such as 3Shape (3Shape Copenhagen, Denmark).

Depicting the design of the hybrid bar framework and the cantilever extension on the basis of the A-P spread

Milling (Subtractive Method)

CAM milling technology is very often referred to as a subtractive process. It involves taking a block of material and cutting away everything that is not necessary until the final restoration is procured. By improving restoration accuracy, speeding up their delivery, and raising patient satisfaction, the adoption of multi-axis milling machines has boosted the efficiency of CAD/CAM dentistry. However, they inevitably have some restrictions, such as those related to milling machine size, price, and kind (4-axis or 5-axis).

Printing Techniques

Additive processes which involve addition of material layer by layer to build the final product. In a study done by Eun-Jeong et al, where they compared overall accuracy of dental restorations fabricated using additive and subtractive techniques, additive techniques fared better(3,43)(4).

Basically three different 3D printing technologies (additive process) are being used in the dental industry: stereolithography apparatus, digital light projection and direct metal laser sintering (DLMS or DMLS or just MLS)(44). Each and every system varies in the different types of materials available and how these materials are solidified and being used.

Conclusion

With the development of digital dentistry, the manufacturing of implant prosthesis has become faster, easier and more efficient. However, it is important to focus on the design of the prosthesis, to achieve desirable and sustainable results.

REFERENCES

1. Guo S, Chen Y, Mallineni SK, Huang S, Liu B, Zhang S, Lu C. Feasibility of oral health evaluation by intraoral digital photography: a pilot study. J Int Med Res. 2021 Feb;49(2):300060520982841
2. Daou EE. Comparison of fit accuracy of three-unit fixed ceramic-CoCr dental prostheses fabricated by three different techniques. Int J Prosthodont. 2021 Feb 19;34(5):642–9.
3. Henkel GL. A comparison of fixed prostheses generated from conventional vs digitally scanned dental impressions. Compend Contin Educ Dent. 2007 Aug;28(8):422–4, 426–8, 430–1.
4. Bae EJ, Jeong ID, Kim WC, Kim JH. A comparative study of additive and subtractive manufacturing for dental restorations. J Prosthet Dent. 2017 Aug;118(2):187–93.
5. Rodriguez AM, Aquilino SA, Lund PS. Cantilever and implant biomechanics: a review of the literature. Part 1. J Prosthodont. 1994 Mar;3(1):41–6.
6. Rodríguez V, Tobar C, López-Suárez C, Peláez J, Suárez MJ. Fracture Load of Metal, Zirconia and Polyetheretherketone Posterior CAD-CAM Milled Fixed Partial Denture Frameworks. Materials [Internet]. 2021 Feb 18;14(4). Available from: http://dx.doi.org/10.3390/ma14040959
7. Sadowsky SJ. The implant-supported prosthesis for the edentulous arch: design considerations. J Prosthet Dent. 1997 Jul;78(1):28–33.
8. McAlarney ME, Stavropoulos DN. Theoretical cantilever lengths versus clinical variables in fifty-five clinical cases. J Prosthet Dent. 2000

Mar;83(3):332–43.
9. Padhye NM, Lakha T, Naenni N, Kheur M. Effect of crown-to-implant ratio on the marginal bone level changes and implant survival - A systematic review and meta-analysis. J Oral Biol Craniofac Res. 2020 Oct;10(4):705–13.
10. Worthington P, Bolender CL, Taylor TD. The Swedish system of osseointegrated implants: problems and complications encountered during a 4-year trial period. Int J Oral Maxillofac Implants. 1987 Spring;2(2):77–84.
11. Taylor RL, Bergman GF. Laboratory Techniques for the Brånemark System. Quintessence Publishing (IL); 1990. 79 p.
12. T. J. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws [Internet]. Vol. 1, Implant Dentistry. 1992. p. 162. Available from: http://dx.doi.org/10.1097/00008505-199205000-00019
13. Rasmussen EJ. Alternative prosthodontic technique for tissue-integrated prostheses. J Prosthet Dent. 1987 Feb;57(2):198–204.
14. Favot LM, Berry-Kromer V, Haboussi M, Thiebaud F, Ben Zineb T. Numerical study of the influence of material parameters on the mechanical behaviour of a rehabilitated edentulous mandible. J Dent. 2014 Mar;42(3):287–97.
15. Taylor T. Twenty years of progress in implant prosthodontics [Internet]. Vol. 88, The Journal of Prosthetic Dentistry. 2002. p. 89–95. Available from: http://dx.doi.org/10.1016/s0022-3913(02)00051-3
16. Carr AB, Stewart RB. Full-arch implant framework casting accuracy: preliminary in vitro observation for in vivo testing. J Prosthodont. 1993 Mar;2(1):2–8.
17. Duda T, Venkat Raghavan L. 3D Metal Printing Technology [Internet]. Vol. 49, IFAC-PapersOnLine. 2016. p. 103–10. Available from: http://dx.doi.org/10.1016/j.ifacol.2016.11.111
18. Cox J, Zarb G. Alternative prosthodontic superstructure designs. Swed Dent J Suppl. 1985;28:71–5.
19. Staab GH, Stewart RB. Theoretical assessment of cross sections for cantilevered implant-supported prostheses. J Prosthodont. 1994 Mar;3(1):23–30.
20. Mericske-Stern RD, Taylor TD, Belser U. Management of the edentulous patient. Clin Oral Implants Res. 2000;11 Suppl 1:108–25.
21. de Carvalho GP, Franco AG, Kreve S, Ramos E, Dias S, do Amaral FB. Polyether ether ketone in protocol bars: Mechanical behavior of three designs. J Int Oral Health. 2017;9(5):202.
22. von Gonten AS, Medina T Jr, Woolsey GD, Hill DR. Modifications in the design and fabrication of mandibular osseointegrated fixed prostheses frameworks. J Prosthodont. 1995 Jun;4(2):82–9.
23. Atwood DA, Coy WA. Clinical, cephalometric, and densitometric study of reduction of residual ridges. J Prosthet Dent. 1971 Sep;26(3):280–95.
24. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. 1972. J Prosthet Dent. 2003 May;89(5):427–35.
25. Zarb GA, Schmitt A. THE EDENTULOUS PREDICAMENT. II: THE LONGITUDINAL EFFECTIVENESS OF IMPLANT-SUPPORTED OVERDENTURES [Internet]. Vol. 127, The Journal of the American Dental Association. 1996. p. 66–72. Available from: http://dx.doi.org/10.14219/jada.archive.1996.0032
26. Heydecke G, McFarland DH, Feine JS, Lund JP. Speech with maxillary implant prostheses: ratings of articulation. J Dent Res. 2004 Mar;83(3):236–40.
27. Laurell L. Occlusal forces and chewing ability in dentitions with cross-arch bridges. Swed Dent J Suppl. 1985;26:160p.
28. Jemt T, Lindén B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Brånemark implants: from prosthetic treatment to first annual checkup [Internet]. Vol. 1, Implant Dentistry. 1992. p. 303. Available from: http://dx.doi.org/10.1097/00008505-199200140-00014
29. Eames WB. The casting misfit: How to cope. J Prosthet Dent. 1981 Mar;45(3):283–5.
30. Muley P, Kale L, Choudhary S, Aldhuwayhi S, Thakare A, Mallineni SK. Assessment of Accessory Canals and Foramina in the Mandibular Arch Using Cone-Beam Computed Tomography and a New Classification for Mandibular Accessory Canals. Biomed Res Int. 2022 Feb 14;2022:5542030.
31. Al-Fadda SA, Zarb GA, Finer Y. A comparison of the accuracy of fit of 2 methods for fabricating implant-prosthodontic frameworks. Int J Prosthodont. 2007 Mar;20(2):125–31.
32. Eliasson A, Wennerberg A, Johansson A, Ortorp A, Jemt T. The precision of fit of milled titanium implant frameworks (I-Bridge) in the edentulous jaw. Clin Implant Dent Relat Res. 2010 Jun 1;12(2):81–90.
33. Tiossi R, Gomes ÉA, Faria ACL, Rodrigues RCS, Ribeiro RF. Biomechanical behavior of titanium and zirconia frameworks for implant-supported full-arch fixed dental prosthesis. Clin Implant Dent Relat Res. 2017 Oct;19(5):860–6.
34. Koizumi H, Ishii T, Okazaki T, Kaketani M, Matsumura H, Yoneyama T. Castability and mechanical properties of Ti-15Mo-5Zr-3Al alloy in dental casting. J Oral Sci. 2018;60(2):285–92.
35. Stimmelmayr M, Edelhoff D, Güth JF, Erdelt K, Happe A, Beuer F. Wear at the titanium-titanium and the titanium-zirconia implant-abutment interface: a comparative in vitro study. Dent Mater. 2012 Dec;28(12):1215–20.
36. Bhering CLB, Mesquita MF, Kemmoku DT, Noritomi PY, Consani RLX, Barão VAR. Comparison between all-on-four and all-on-six treatment concepts and framework material on stress distribution in atrophic maxilla: A prototyping guided 3D-FEA study [Internet]. Vol. 69, Materials Science and Engineering: C. 2016. p. 715–25. Available from: http://dx.doi.org/10.1016/j.msec.2016.07.059
37. Shaikh SA, Rai P, Aldhuwayhi S, Mallineni SK, Lekha K, Joseph AM, Kumari VV, Meshramkar R. Comparative Evaluation of Stress Acting on Abutment, Bone, and Connector of Different Designs of Acid-Etched Resin-Bonded Fixed Partial Dentures: Finite Element Analysis. Front Bioeng Biotechnol. 2022 Apr 26;10:798988.
38. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Implant Dent. 1996;5(4):296.
39. Michalakis KX, Hirayama H, Garefis PD. Cement-retained versus screw-retained implant restorations: a critical review. Int J Oral Maxillofac Implants. 2003 Sep;18(5):719–28.
40. Jemt T, Lekholm U. Measurements of bone and frame-work deformations induced by misfit of implant superstructures. A pilot study in rabbits. Clin Oral Implants Res. 1998 Aug;9(4):272–80.
41. Natali AN, Pavan PG, Ruggero AL. Evaluation of stress induced in peri-implant bone tissue by misfit in multi-implant prosthesis. J Prosthet Dent. 2006 Nov;96(5):338.
42. Katsoulis J, Takeichi T, Sol Gaviria A, Peter L, Katsoulis K. Misfit of implant prostheses and its impact on clinical outcomes. Definition, assessment and a systematic review of the literature. Eur J Oral Implantol. 2017;10 Suppl 1:121–38.
43. Khan MAA, Sheikh AK, Al-Shaer BS. Evolution of Metal Casting Technologies: A Historical Perspective. Springer; 2016. 43 p.
44. Awad A, Fina F, Goyanes A, Gaisford S, Basit AW. 3D printing: Principles and pharmaceutical applications of selective laser sintering. Int J Pharm. 2020 Aug 30;586:119594.