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Implant Superstructures- A Narrative Review

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Abstract:
Implants can be utilized similarly to natural teeth to support various types of dental restorations, including single crowns, bridges, fixed-removable prostheses and overdentures. The resulting structure is referred to as a superstructure, which may be entirely implant-supported or supported by both implants and natural teeth that are commonly known as hybrid or tooth/implant-borne restorations. Superstructures are connected to implants by abutments, with angled abutments often employed to achieve parallelism and a single path of insertion, especially when multiple implants are involved. These superstructures can be classified as removable, fixed/removable or fully fixed, depending on clinical and patient-specific needs. Removable superstructures are designed to be taken out by the patient for cleaning, offering ease of maintenance. While fixed/removable restorations combine the stability of fixed prostheses with the retrievability of removable ones. Fully fixed superstructures are permanently attached and offer high comfort and function but require more complex maintenance. The integration of CAD/CAM technology has significantly advanced the precision, fit, and efficiency in designing and fabricating these restorations, enabling customized solutions with improved mechanical performance. In conclusion, the versatility of implant superstructures enhanced by modern digital workflows allows for functional, and esthetic outcomes in wide range of clinical scenarios.

Key Word: *Implant superstructures, CAD-CAM, Removable superstructures, Fixed superstructures, Fixed-detachable superstructures*

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I. Introduction

Dental implants have been used for over 50 years to replace missing teeth, offering a reliable alternative to dentures and bridges.Common causes of tooth loss include periodontitis, caries, trauma, and genetic conditions.[1] Implant success depends on osseointegration, a direct connection between living bone and the implant surface. A dental implant system includes a fixture placed in bone and an abutment that connects the implant to the prosthetic crown. The implant-abutment connection (IAC) plays a key role in the stability and strength of the final restoration.[2] Implant superstructures are the prosthetic components supported by implants. They may be single crowns, bridges, or full dentures, and are either cement- or screw-retained. CAD/CAM technology now allows fabrication of superstructures using materials like zirconia, titanium, and cobalt-chromium.[3] While offering improved aesthetics and precision, concerns remain regarding long-term strength and fit. Implant overdentures (IODs), in use since the 1980s, are another effective option for full-arch restoration.[4]

II. History

Dental implants date back to 2500 BC, when Egyptians used gold wire to stabilize teeth, and by 600 AD, Mayans placed shells into jaws, showing early osseointegration.Between the 1500s and 1800s, attempts at tooth transplantation and metal implants often failed due to poor biocompatibility. Modern implantology began in 1913 with Greenfield's iridio-platinum implant, followed by Vitallium screws in the 1930s. The mid-20th century introduced subperiosteal and blade implants.[5,6] A breakthrough came in 1978 when Brånemark introduced titanium implants based on osseointegration, transforming implant dentistry.[7] The 1980s saw further innovations, including hydroxyapatite coatings, plasma-sprayed surfaces, and one-stage surgical techniques, enhancing long-term success.[8]

III. Implant Bio-Materials

Implant biomaterials are broadly classified based on their composition into metals and biodynamic activity. (fig.1)

Fig.1: Classification of Implant Bio materials

Bio-dynamic activity	Chemical Composition		
	Metals	Ceramics	Polymers
Bio tolerant	Gold Co-Cr alloys Stainless steel Niobium Tantalum		Polyethylene Polyamide Polymethylmethacrylate Polytetrafluroethylene Polyurethane
Bio inert	Commercially pure titanium Titanium alloy (Ti-6AL-4U)	Al oxide Zirconium oxide	
Bioactive		Hydroxyapatite Tricalcium phosphate Bio glass Carbon-silicon	

Polymers gained dental relevance after Hodosh (1969) demonstrated their biocompatibility, leading to polymethacrylate tooth replicas. They offer esthetics and easy handling but lack strength and tissue integration.[10] Titanium and Ti-6Al-4V remain standard for endosseous implants due to excellent osseointegration, despite esthetic limitations.[11] Cobalt-chromium and stainless steel are used in specific cases but pose allergy and corrosion risks.[12] Yttria-stabilized zirconia (Y-TZP) provides superior esthetics and soft tissue response, ideal for anterior zones.[13] Titanium-zirconium alloys like Roxolid offer higher strength for narrow-diameter implants.[14] PEEK and BioHPP are metal-free polymers with bone-like elasticity, suitable for patients with metal sensitivity.[15] Graphene coatings enhance osseointegration and may improve future implant surfaces.[16]

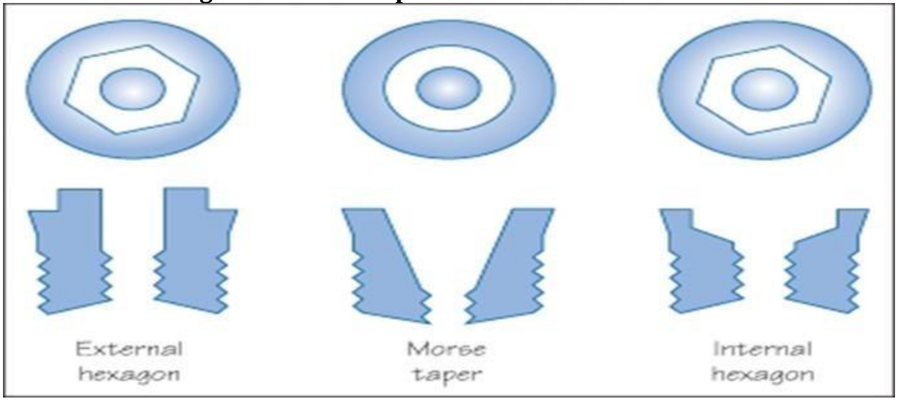
IV. Abutments

Implantology is guided by prosthetic needs, with implant placement, osseointegration, and abutment selection key to success. The abutment supports the prosthesis or superstructures a metal framework for retaining removable or fixed restorations.[17]

V. Implant-Abutment Connections

Implant-abutment connections are key to implant stability, load transfer, and tissue health. Evolving since Branemark's osseointegration, designs aim to reduce mechanical and biological issues.[18] External hex connection, though simple and prosthetically convenient, is prone to micro-movement and screw loosening under lateral forces, increasing the risk of bacterial leakage and crestal bone loss, especially in bruxers. Frequent retightening is often needed.[18] (Fig.2) Internal hex design offers better anti-rotational stability and load distribution, reducing micro-leakage and improving torque retention. However, minor micro-movements and preload loss may still contribute to marginal bone resorption over time.[18] (Fig.2) Conical (Morse taper) connection uses a friction-fit interface with minimal microgap, offering excellent torque preservation and stress distribution. While it supports long-term bone stability, it is technique-sensitive and may be difficult to retrieve, especially in screwless systems.[18] (Fig.2)

Fig. 2: Different Implant-Abutment Connections



Choosing the right connection is critical to ensuring long-term implant success and minimizing biological and mechanical complications.[18]

VI. Types Of Implant Superstructures

Implant superstructures refer to the prosthetic components that are attached to dental implants to restore function and aesthetics. These can be broadly categorized into three type: fixed, fixed-detachable, and removable. Fixed superstructures are permanently attached via cement or screws and cannot be removed by the patient. They offer high stability, function, and aesthetics which are ideal for those seeking a permanent, natural-feeling solution. Fixed-detachable superstructures are screw-retained by the dentist and removable for maintenance. Common in full-arch cases like All-on-4, they balance durability with accessibility. Removable superstructures (e.g., overdentures) are patient-removable and attach via bars, magnets, or locators. They're easier to clean but may offer less stability than fixed options. Selection depends on patient needs, hygiene access, and prosthetic goals.

VII. Fixed Superstructures

Fixed superstructures are permanently attached via cement or screws and cannot be removed by the patient.

Biomechanics & Material Selection - Materials on occlusal surfaces critically influence the longevity of implant-supported prostheses. Historically, gold frameworks with acrylic occlusal surfaces were used to absorb shock. Acrylic resin, being softer, mitigates peak forces during hard object chewing, whereas rigid materials transfer higher impact loads directly to the implant–bone interface, increasing risk of damage over time.[19]

Single-Tooth Restorations - Implant crowns are either cement-retained, where the abutment is screw-fixed and the crown is cemented on like a natural tooth, or screw-retained, where the abutment and crown form one unit that's directly screwed into the implant.[20]

Cementation Factors - Retention depends on taper, surface area/height, surface finish, and cement type. Ideal 6° taper on implant abutments provides three to four times more retention than typical natural-tooth preparations (15–25° taper). Machined abutments also offer greater height and surface area, further boosting retention. Roughening abutments enhances cement grip, but most clinicians can rely on the existing precision of machined surfaces. Using provisional cement like Temp-Bond offers ideal retrievability—a key benefit over permanent cements. Correctly cemented implant prostheses can be removed with minimal effort, offering both stability and serviceability.[21,22]

Screw-Retention - Screw-retained prostheses rely on precise torque to generate preload and clamping force. Accurate fit between abutment and implant distributes vertical loads effectively and minimizes screw stress. However, misfits in cast frameworks lead to pivot points and microgaps, which can result in screw loosening under offset loading.Multiple studies confirm that truly passive casting is nearly impossible, and misfit increases mechanical complications.[23]

Cement vs. Screw Retention - Cement-retained prostheses offer superior passivity, stronger porcelain support, better esthetics, easier lab procedures, reduced cost, and faster chair-time, while still being retrievable using provisional cement techniques. Screws are typically only recommended when abutment height or space is limited.

Fixed Implant-Supported Bridges - Bridges follow similar principles that are cemented or screwed. Prosthesis type ranges from cast-gold or stress-broken to PFM and all-ceramic options (e.g., zirconia). High-noble metal bridges remain the benchmark for precision, biocompatibility, and strength. PFM and CAD/CAM zirconia frameworks offer esthetics with durable support.[24] (fig 3).

Fig.3: PFM fixed bridge

Tooth-Implant Connected FPDs & Intrusion Risk - Connecting natural teeth to implants can invite tooth intrusion, though newer research suggests rigid connectors and strong cement significantly reduce this risk. Intrusion occurs in ~3–4% of cases long-term, influenced by clinician experience and design factors. Some studies show similar survival between mixed (tooth-implant) and pure implant-supported bridges over 5–10 years when rigid designs are used. [25,26]

VIII. Fixed-Detachable Superstructers

Fixed-detachable superstructures are screw-retained by the dentist and removable for maintenance. Hybrid dentures aim to replace removable full dentures with implant-supported fixed options, especially when improving retention and comfort is a priority. Two main types exists, they are Metal-ceramic and Metal-acrylic fixed prostheses.

Metal-Ceramic Fixed Prostheses - A ceramic layer bonded to a cast metal framework, either cemented to abutments or screw-retained.

Hybrid (Metal-Acrylic) Prostheses -Initially introduced for unstable mandibular dentures, these use a metal substructure with acrylic resin teeth.

The choice of restoration depends on intra-arch space, esthetic needs (e.g., lip support), and visibility of soft tissue during function.[27]

Advantages of Hybrid Prostheses includes excellent esthetics at lower cost , shock absorption during occlusion, viable in tilted or axially placed implants for resorbed maxillae, more comfortable than conventional full dentures.[28]

However, there are some disadvantages such are food entrapment, speech changes oral hygiene challenges.[28]

Biomechanics of Cantilevers - The fixed-removable hybrid prosthesis resembles a flangeless denture supported by multiple implants, without tissue contact. Originally developed by Branemark, these prostheses place implants in the anterior region, with posterior cantilevers extending from the framework.[29]

Cantilever mechanics:
Deformation $\propto$ force × length^3
Deformation $\propto$ 1 / (height^3 × width × modulus of elasticity)
Keep cantilevers <20 mm with ≥5 implants & <15 mm with 4 implants
Maxillary cantilevers should be shorter due to softer bone
Maintain 1to 2 mm clearance for hygiene.[29,30]

Material guidelines:

Yield strength >300 MPa, Elastic modulus >80,000 MPa, Type IV gold or silver-palladium alloys recommended.Use acrylic resin teeth with minimal cusp angles to reduce lateral stress and absorb shock.[30,31]

Branemark stated that “critical to the maintenance of osseointegration the carefully controlled and prosthetic-induced loading of the implant-tissue interface” and emphasized precise prosthetic fit (within 10 µm) to maintain osseointegration. Controlled dynamic and static loading is essential to stimulate bone remodeling and avoid implant failure.[32]

Zarb & Jansson described two framework types they are Metal-dominant frameworks with minimal acrylic & Wraparound designs with extensive acrylic base.Esthetics are more demanding in the maxilla due to resorption patterns (superior, medial, posterior), often requiring prosthetic gingiva. Mandibular designs are usually more hygienic and esthetically acceptable.[33]

All-on-4 Concept- Introduced by Malo et al. in 2003, the All-on-4 technique revolutionized full-arch rehabilitation by utilizing only four implants to support a complete prosthesis. The two anterior implants are placed axially, while the two posterior implants are tilted distally typically at 30 to 45 degrees to avoid anatomical limitations like the maxillary sinus, inferior alveolar nerve, or mental foramen.(fig.4) Clinical Benefits Bypasses anatomical constraints: Allows implant placement in areas with reduced vertical bone height without the need for bone grafting. Maximizes prosthetic support: Tilting posterior implants increases anterior-posterior (A-P) spread, improving the load distribution and allowing for shorter cantilevers. Reduces treatment time and cost: Implants can often be immediately loaded, minimizing patient visits and eliminating healing delays. Preserves bone and facial structure: Strategic placement helps prevent further resorption of the alveolar ridge.[34]

Fig.4. ALL on 4 concept

IX. Removable Superstructures

An overdenture is defined as a removable dental prosthesis that sits over retained roots or implants, enhancing support, stability, and function (Harold W. Preiskel).

The advent of osseointegration by Brånemark et al. (1982) transformed prosthodontics. For edentulous patients, implant-retained overdentures offer a balance between function, cost, and maintenance. Compared to fixed prostheses, overdentures are less invasive, cost-effective, and easily maintainable, especially in cases of advanced bone atrophy. [35,36]

Implant Requirements Mandible: Typically 2 implants (canine region) suffice; single-implant overdentures are also viable. Maxilla: Requires 4 to 6 implants due to less dense bone. The minimum number of implants remains a debated topic.[35,36]

Historically,in 1856 Ledger used "fangs" under prosthetic plates, from 1888to 1961 Root-supported, telescopic, and bar-retained overdentures evolved (Essig, Dolder) and around in 1980's Implants introduced with consistent osseointegration results.[36]

Prosthetic Options (Misch Classification) Type 4 – RP-4: Fully implant-supported, removable prosthesis. Requires ≥5 implants in mandible, 6–8 in maxilla. Utilizes bars or superstructures for rigid retention. Type 5 – RP-5: Implant and mucosal support, commonly with 2–4 implants. Offers cost-efficiency, easier maintenance, and future upgradability. Bone loss may progress faster than in RP-4 or fixed prostheses.[37]

Overdenture Attachments and Movement Attachments (O-rings, bars, magnets) allow various prosthesis movement patterns (PM-0 to PM-6):[37,38]

PM-0: Rigid prosthesis, no movement (e.g., Hader bar with clip).
PM-1: Single axis movement (e.g. hinge)
PM-2: Hinge-like rotation (usually anterior-posterior axis) (e.g.,Dolder bar without spacer, Hader bar in specific orientation)
PM-3: Hinge-type + apical movement (e.g., Dolder bar with spacer).
PM-4: Mesial-distal + lateral (2 planes) (e.g., magnets).

PM-6: Full 6-direction movement (occlusal, gingival, mesial, distal, facial, lingual) (e.g.,Independent O-rings, ERA attachments)

Implant positioning and attachment design directly influence motion and stress distribution. The advantages are Improved retention, chewing efficiency, and psychological satisfaction. Less invasive, lower cost, and future convertibility to fixed prostheses. Easier hygiene access and muscle tone preservation due to stability.[39] There are disadvantages such as Bulky design in cases of extensive ridge resorption. Patients may resist due to the removable nature, especially those dissatisfied with prior dentures. The indications are Elderly patients with poor adaptation to conventional dentures. Edentulous patients with congenital or surgical defects. Cases where fixed prostheses are contraindicated due to health or finances.The contraindications are Comfortable and satisfied denture wearers.

Inadequate bone for implant placement. Systemic risks: uncontrolled diabetes, immunosuppression, substance abuse.[40,41,42]

Implant overdentures offer a functional and economical alternative to fixed prosthetics, especially in older or medically compromised patients. Studies show significantly higher satisfaction and comfort with two-implant mandibular overdentures compared to conventional dentures.[43,44] Esthetics can be enhanced with custom flanges and labial support. Home care and professional maintenance are more manageable than fixed restorations. Implant overdentures should be the first-line implant option for many edentulous patients, particularly when affordability, anatomy, or age are considerations.Ultimately, clear patient education on the benefits, limitations, and maintenance of overdentures ensures realistic expectations and long-term success.[45,46]

X. Role Of CAD-CAM

Implant-prosthesis planning should begin before implant selection or placement, following the reverse planning concept. This ensures implant positioning is guided by prosthetic requirements, not just bone availability.[47] The introduction of CT imaging has greatly enhanced visualization of anatomical structures, allowing for 3D planning and virtual implant placement using dedicated software.[48] When combined with CAD/CAM and stereolithography, this data enables the fabrication of precise surgical guides, improving implant accuracy and outcomes. Despite its apparent simplicity, guided surgery demands careful case selection, detailed planning, and an experienced team to minimize complications.[49]

CAD/CAM systems allow for digital design and fabrication of components such as custom abutments, implant bridges, bars, and surgical guides. Initial systems like CEREC (chairside) and PROCERA (indirect) revolutionized workflows. Modern scanners, such as the NobelProcera with conoscopic holography, offer high precision, even in complex geometries. Subtractive manufacturing (e.g., milling) and additive techniques like Direct Metal Laser Sintering (DMLS) now produce restorations in materials such as zirconia, titanium, lithium disilicate, and ceramics. These processes reduce clinical and lab time while improving fit and accuracy.[50.51] CAD/CAM workflows are available chairside, in labs, or through centralized centers. While the technology enhances predictability and efficiency, success still depends on proper clinical execution, respect for biological principles, and precise mechanical planning.[52]

XI. Conclusion

Implant superstructures are essential to the long-term success of implant-supported restorations, directly impacting both function and esthetics. A well-designed superstructure ensures proper load distribution, passive fit, and soft tissue support, all of which are critical for peri-implant health and patient satisfaction. Advances in prosthetic materials, abutment designs, and CAD/CAM fabrication have greatly improved the precision and efficiency of superstructure fabrication. However, clinical success still relies on thoughtful case selection, prosthetically driven planning, and careful attention to occlusion and biologic width. When properly executed, implant superstructures provide predictable, durable, and esthetically pleasing outcomes that restore both form and function.

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