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Biomechanics of Screw and Cement Retained Restoration in Implant Prosthesis: A Systemic Review

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Abstract: *Implant supported restoration can be secured by screw retained orcement retained. Knowing about biomechanics of screw and cement retained restorations is important for the success of the prosthesis. The definite indications and contraindications to use specifically the screw or cement is unclear. The reasons for the success and failure of screw retained and cement retained dental implant prosthesis in the oral cavity are reviewed. Hence the Literature search was carried out using electronic database search in PubMed and Google scholar for articles from 1990–2022 and a systemic review was undertaken to study the biomechanics of screw retained and cement retained crowns and their success rates and complications*

Keywords: *"Dental implants", "screw retained restorations", "cement retained restorations", "biomechanics of dental implants", "success rates" and "systemic review"*

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I. Introduction

The principles of biomechanics comprise of all the interactions between the body (tissues) and the forces acting upon it (directly or via different medical devices). Besides the mechanical aspects, the tissues response is also studied. Understanding and applying these principles is vital for the researchers in the field of oral implantology, but they must be equally known by the practitioners. From the planning stages to the final prosthetic restoration, they are involved in each and every aspect.

Dental implants provide support for the prosthesis and transfer the occlusal forces to the supporting bone. The transfer of the forces to the supporting bone is determined by the resultant force transferred from the prosthesis to the implant and the amount of implant area available to transfer the force to the supporting bone.

A force applied to a dental implant rarely is directed absolutely longitudinally along a single axis. In fact, three dominant clinical loading axes exist in implant dentistry: (1) mesiodistal, (2) faciolingual, and (3) occlusoapical .A single occlusal contact most commonly results in a three-dimensional occlusal force. Importantly, this three-dimensional force may be described in terms of its component parts (fractions) of the total force that are directed along the other axes. For example, if an occlusal scheme on an implant restoration is used that results in a large magnitude of force component directed along the faciolingual axis (lateral loading), then the implant is at extreme risk for fatigue failure. The process by which three-dimensional forces are broken down into their component parts is referred to as *vector resolution* and may be used routinely in clinical practice for enhanced implant longevity. [1]

Conventional dental implants have a three-piece design. The three components are the implant post /screw/fixture, the abutment that attaches to the implant post, and the prosthesis or tooth restoration, which could be a crown, bridge, or denture.The crown preferably made up of alloy or all ceramic or porcelain fused alloy. Retaining any type of crown with the implant abutment is achieved by mechanical component (screw) or a chemical medium called cements are used. The definite indications and contraindications to use specifically the screw or cement is unclear

During prosthetic implant treatment planning, different prosthetic modalities should be considered and related to many factors, such as probability of mechanical and biological complications, aesthetical outcome and financial concerns. Restorations may be screw- or cement retained to the implant, or both, through a cemented prosthesis with lingual or palatal fastening screws [2]. Screw-retained systems are usually indicated for prostheses with multiple abutments to allow the prostheses to be removed for cleaning and possible repairs. Cement-retained systems are ideal where esthetics are the primary consideration, as these systems can compensate for an unfavorable angulation of an implant in relation to a crown; they are also simpler to fabricate, decreasing possible laboratory complications [2].

Screw-retained restorations are associated with more sophisticated clinical and laboratory procedures, which increase the total cost of implant treatment. Moreover, the retaining screw seems to be more prone to lateral bending, tipping and elongation forces, which may result in screw loosening or screw fracture [2, 3]. To eliminate such disadvantages as well as to broaden the material spectrum to include additional restorative materials, i.e. all-ceramic materials, cement-retained restorations can be used.

Many practitioners do not consider cement retention an option in implant-supported restorations because they believe that cemented restorations are not retrievable [3]. Cement, when used appropriately, can retain implant supported prostheses and provide retrievability [4]. In addition, cement-retained prostheses have superior occlusion, esthetics, passivity and loading characteristics when compared with screw-retained prostheses [5]. Cement retention has been used in fixed prosthodontics for almost 100 years, and a significant and well-documented history has developed out of its use [3].

Screw-retainedframeworks can be made from titanium, Co-Cr base alloys and zirconia.Titanium frameworks are usually veneered with acrylic or ceramic veneering materials, zirconia frameworks with feldspathic ceramics. Alternatively the restoration can be designed in full contour zirconia.

In cement – retained,Depending on abutment material, size and design (retention/wall angles) various cementation materials, ranging from temporary cements to adhesive resin cements, are used. With retentive abutment designs conventional cementation protocols with zinc-phosphate or glass-ionomer cements are successfully used.Due to the high difficulty to remove remnants of resin cements and adhesive resin cements, even more in posterior implant sites with difficult access, this type of cement is not recommended for cementation of multiple-unit restorations.

The definite indications and contraindications to use specifically the screw or cement is unclear.The reasons for the success and failure of screw retained and cement retained dental implant prosthesis in the oral cavity are reviewed.

According to Sailer et al, for cemented single crowns the estimated 5-year reconstruction survival was 96.5% , for screw-retained single crowns it was 89.3% (P = 0.091 for difference). The 5-year survival for cemented partial fixed dental prostheses (FDPs) was 96.9% , similar to the one for screw-retained partial FDPs with 98% (P = 0.47) [6] and according to Sami sheriff, the overall 5-year implant survival rate was 96% in the anterior maxilla, with no differences between screw- and cement retained restorations [7].

Literature search was carried out using electronic database search in PubMed and Google scholar for articles from 1990–2022 with keywords such as “Dental implants”, “screw retained restorations”, “cement retained restorations”, “biomechanics of dental implants”, “success rates”and “systemic review”. A total of 150 articles were identified out of which 94 were discarded as they were not specific to the biomechanics of screw retained and cement retained crowns, after screening the remaining articles a total of 27 articles were selected for the review . Standard text books of dental implantology were also referred, the same was reviewed and analyzed to study the biomechanics of screw retained and cement retained crowns and their success rates and complications were also reviewed.

II. Discussion

Thesystematic review is carried out by dividing the topic into two subheadings that is 1) mechanical factors influencing the success and failures of prosthesis 2) biological factors influencing the success and failures of prosthesis

MECHANICAL FACTORS	BIOLOGICAL FACTORS
A)Retention 1.Abutment design 2.Screw design in screw retained restorations 3. Cements on bonding and integrity on crown and abutment.	A)Esthetics
B)Favorable and unfavorable forces	B)Compatibility in static and dynamic occlusal contacts
C)Torque- iatrogenic forces which influences the success and failure	
D)Prosthesis fit	

MECHANICAL FACTORS

Mechanical Factors which influences the retention and supportfor implant prosthesis:

A) RETENTION

1) ABUTMENT DESIGN

In cement retained, there are several factors that affect the retention such as taper of abutment, surface area and height, surface roughness and type of cement. [3]

Taper greatly affects the amount of retention in cement-retained restorations, machined abutments have mostly 6^0 of taper depending on the concept of ideal tapering proposed by Jorgensen for natural teeth [8].Regarding surface area and height, the subgingival placement of the implants provides longer implant abutment walls and usually more surface area than prepared natural teeth [3]. The minimum abutment height to use cement-retained restorations with predictable retention was documented to be 5 mm [9].Increased surface roughness will offer increased mechanical retention for cements [10]. Various techniques such as diamond burs or grit blastingare used to roughen the implant abutments to provide higher retention [3].Cement selection is one of the most important factors controlling the amount of retention attained for cement-retained restorations [10]. The cement used with implant restorations can be either permanent or provisional, it is the clinician's decision to choose a certain type of cement based on the clinical situation [3].

In screw-retained restorations, retention is obtained by a fastening screw. The loss of retention in screw-retained restorations is demonstrating itself as screw loosening [11].Factors including insufficient clamping force, screw settling, biomechanical overload, off-axis centric forces, implant components and prosthesis misfit, differences in screw material and design. Hex height and implant diameter have also shown to affect the amount of retention of screw-retained restorations [3, 11].

To achieve sufficient clamping force the screw should be torqued 50% to 75% of their yield strength, so it is imperative that all screws be tightened to manufacturers' specifications using a torque control wrench in the initial phase of screw tightening. Screw settling or embedment relaxation will occur shortly after screw tightening due to compression of microscopically rough areas of the screw threads and opposing flanges; therefore, re-torqueing the screw 5 minutes after initial torqueing and again a few weeks later is recommended [3, 11].

2) SCREW DESIGN IN SCREW RETAINED CROWN

The screw design also influence screw retention, screw heads with internal hexagon have shown to remain tighter than those with slots [12]. Tapered head screws have been abandoned because the head/shaft load ratio was found to be 4:1 as opposed to flat head screws using a 1:1 head/shaft ratio, this leads to strained interfaces when using tapered screws that will increase the susceptibility of screw loosening [13].In addition, increasing the screw diameter will increase the preload and therefore the retention of screw-retained restorations. Also, enhancing the implant design by increasing hex height and diameter of implant platform can increase stability and resist screw loosening [14, 15].

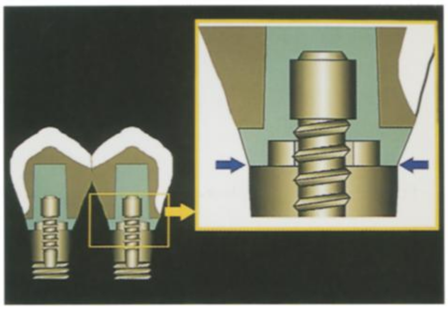
3) CEMENTS ON BONDING AND INTEGRITY OF CROWN AND ABUTMENT

A wide variety of cements exist with varying degrees of strength. There are two main cements available for use in restorative dentistry i.e. provisional and definitive cements [3]. Temporary cements show some advantages, including easy removal of excess cement, sufficient retention in normal situations and easy retrieval of the restoration without damage to abutment or implant [16, 17].

ZOE cement (Temp-Bond NX) is a temporary cement that has gained popularity due to easy manipulation, relatively low cost, and fractional stress relaxation. Stress releasing may be a good quality for cements used for implant prostheses, because implants lack the cushioning effect of the periodontal ligament, unlike natural teeth [18]. However, temporary cements show some disadvantages compared to permanent cements, such as more solubility, lower strength, easier de-bonding of the restoration, and radiolucent appearance in radiography. Washout of temporary cements leads to a gap between restoration margin and the abutment margin that would result in tissue damage at the implant/tissue interface [19]. A survey by Schwarz et al [20] showed that fracture incidence and retention loss of temporary cements were greater than those of permanent cements. (l) Temp-Bond cement mixed with petroleum jelly provides adequate retention for fixed partial dentures or multiple splinted units supported by implants and (2) Temp-Bond cement provides adequate retention for single units supported by implants[3].

The main advantage of permanent cements over temporary ones is their higher degree of retentiveness [19]. Several factors such as resistance/retention form, height, distribution and number of abutments, framework fitness, and the arch receiving the prosthesis (maxilla vs. mandible) can influence the amount of needed retention derived from cement[21,22].

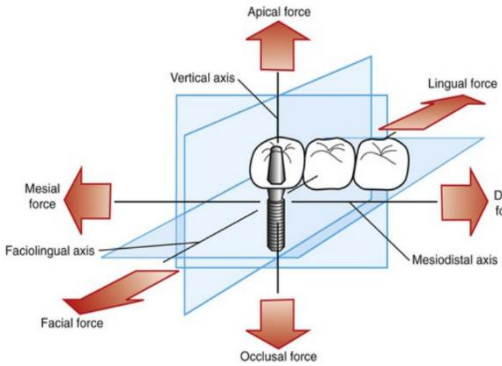
Generally, according to most of the studies that compared tensile strength of different temporary and permanent cements, the order of cements from least to most retentiveness is zinc oxide (with or without eugenol), polycarboxylate, glass ionomer, RMGI, zinc phosphate, and resin adhesive cements [23,24]. In selection among permanent cements, simplicity of removing the excess cement and possible damage to Ti abutments should be considered. According to Agar et al the order of cements from least to most difficult to clean up is zinc phosphate, glass ionomer, and resin cements [25].



Cement-retained multiunit casting showing precise fit of individually torqued abutments. Casting fits on abutments passively because of cement grout [3].

B) FORCES ACTING ON CEMENTED AND SCREW RETAINED CROWNS

Force applied to a dental implant rarely is directed absolutely longitudinally along a single axis. In fact, three dominant clinical loading axes exist in implant dentistry: (1) mesio-distal, (2) facio-lingual, and (3) occluso-apical. A single occlusal contact most commonly results in a three-dimensional occlusal force. Importantly, this three-dimensional force may be described in terms of its component parts (fractions) of the total force that are directed along the other axes. For example, if an occlusal scheme on an implant restoration is used that results in a large magnitude of force component directed along the faciolingual axis (lateral loading), then the implant is at extreme risk for fatigue failure. The process by which three-dimensional forces are broken down into their component parts is referred to as *vector resolution* and may be used routinely in clinical practice for enhanced implant longevity [1].



Forces are three-dimensional, with components directed along one or more clinical coordinate axes: mesiodistal, faciolingual, and occlusoapical (vertical) [1]

Occlusion serves as the primary determinant in establishing load direction. The position of occlusal contacts on the prosthesis directly influences the type of force components distributed throughout the implant system [1].

Visualizing each occlusal contact on an implant restoration in its component parts is necessary. When the contact is broken down into its component parts directed along the three clinical loading axes, a large, potentially dangerous lateral component is observed. Occlusal adjustments consistent with implant-protective occlusion is necessary to eliminate the premature contact which in-turn minimizes the development of such dangerous load components [1].

Angled abutments also result in development of dangerous transverse force components under occlusal loads in the direction of the angled abutment. Implants should be placed surgically to provide for mechanical loading down the long axis of the implant body to the maximum extent possible. Angled abutments are used to improve esthetics or the path of insertion of a restoration, not to determine the direction of load [1].

Three Types of Forces

Forces may be described as compressive, tensile, or shear. Compressive forces attempt to push masses toward each other. Tensile forces pull objects apart. Shear forces on implants cause sliding. Compressive forces tend to maintain the integrity of a bone–implant interface, tensile and shear forces tend to distract or disrupt such an interface. Shear forces are most destructive to implants and bone compared with other load modalities. In general, compressive forces are accommodated best by the complete implant–prosthesis system. Cortical bone is strongest in compression and weakest in shear. Additionally, cements and retention screws, implant components, and bone–implant interfaces all accommodate greater compressive forces than tensile or shear [1]. Many factors interact in a complex manner to produce a load at the bone-implant interface. Offset loading is one factor that can be controlled with prosthesis design.The bone-implant interface survive some degree of offset loading; however, there is increase in the incidence of prosthetic complications such as screw loosening and breakage [26, 27]. As such, prudent control of offset loading is suggested through prosthetic design. The ability to generate vertical or axial loading may be compromised when the choice is made to use screw-retained implant restorations. Axial loading is preferred for implants and the bone-implant interface, and offset loading may be harmful. It is desirable to generate vertical loading over the prosthetic head of the implant [28, 29].

C) TORQUE – ITROGENIC FORCES WHICH INFLUENCES THE SUCCESS AND FAILURE

Minimum and maximum torque when the abutment is screwed into the implant through the torque on the screw, stresses are generated causing elongation of the screw. These stresses generate the preload, a clamping force between the implant and abutment, which is responsible for the stability of the prosthetic system. The preload should be greater than the forces that tend to separate the components in order to keep the components together [30]. The maintenance of preload is dependent on several factors, such as the amount of torque, quality of the fit, lubrication of the screw, and especially the external loads acting on the bolt joint [31]. These factors may decrease the preload on the screw, contributing to its loosening or deformation [32, 33]. When the prosthetic system is under compressive axial loads, a reduction of stresses in the screw is expected because of the decreased friction of the screw threads in contact with the inner surface of the implant. This enables its rotational displacement, with consequent loss of preload [33].

D)PROSTHESIS FIT

The passive fit of implant prostheses has been stressed because of the ankylotic character of implant abutments and because poor fit is correlated with biologic and mechanical complications [34,35].Many authors believe that a cement retained restoration is more likely to achieve passive fit than a screw-retained one[3,36]. This increased passivity of cement-retained restorations rests on the assumption that the cement could act as a shock absorber and reduce stress to bone and implant-abutment structure [3].Conversely, screw-retained prosthesis without precise fit between crown and abutment may create substantial stress within the prosthesis, the implant, and surrounding bone [36].However, the main factors that affect the prosthesis fit depends on accuracy achieved in the fabrication process, including impression technique, master cast accuracy, component tolerance, casting tolerance and skill of the technician, while the type of retention does not play a role in transferring or compensating for inaccuracies of prosthesis fabrication [37].Screw-retained restorations have been found to produce tighter margins than their cemented counterparts[38]. As a consequence with cement-retained restorations there is always a risk of colonization of the space with microflora which may result in cement dissolution and gingival inflammation [61, 62]. Passive fit of screw-retained restoration can be improved by laser welding of the prosthesis framework [63, 64]. To enhance the fit of single cast framework spark erosion is another proposed technique. Sectioning and soldering the framework has been reported to improve some discrepancies but it may still not create absolute fit [65]. One of the most recent approaches to improve passivity of fit is using the laser scanned computer numeric controlled– milled titanium (computer aided design/ computer aided manufacturer) [66].

BIOLOGICAL FACTORS

A) ESTHETICS

When the implant is placed in the ideal position, predictable esthetics can be achieved with either screw- or cement-retained restorations [45].One of the debates regarding using screw retained restorations is the screw access channel that may be placed in an esthetic area [3] .When there is difficulty in placing the implant in an ideal position for any anatomic limitation, the pre-angled or custom abutments can be used so that the screw access channel is relocated away from esthetic area [45]. The use of an opaquer in combination with a resilient composite offered a significant esthetic improvement of implant restoration [46].

B)COMPATIBILTY IN STATIC AND DYNAMIC CONTACTS

The selection of screw retention or cement retention as an attachment mechanism has a significant impact on the occlusion. Screws or screw holes in the occlusal surfaces of teeth provide poor esthetics and disrupt the occlusal surfaces. Screw holes have used up a large percentage of the occlusal table as well as interfering with the contacts that axially load the implants. It can be concluded that the cement-retained implant restoration is superior in both esthetics and occlusion. This effect carries over to protrusive and lateral protrusive movements in terms of ability to generate occlusion. With the cement-retained implant restoration, anatomic surfaces of all the teeth are present to develop protrusive and lateral protrusive relationships. Screw-retained implant prostheses may lack the proper anatomy on the cuspids and central incisors for the smooth transition into protrusive and lateral protrusive movements; thus, anterior guidance may be compromised. Generating optimum occlusion is important to all clinicians regardless of their individual philosophy, and when the choice is made to use screw retained prostheses, occlusion is compromised [3].

BIOLOGICAL COMPLICATIONS

The biologic complication such as ‘presence of fistula/suppuration’ was statistically higher for cemented restorations. These results are consistent with several other reports observing that cement remnants represent a significant risk for peri-implant infection and should be handled with great caution [47].

It has been shown that incomplete removal of cement may result in peri-implant inflammation, soft tissue swelling, soreness, bleeding or exudation on probing, and resorption of peri-implant bone. The solution for these clinical situations is using either screw-retained restorations or custom abutments for cement restoration with margin following the anterior gingival contour [41].

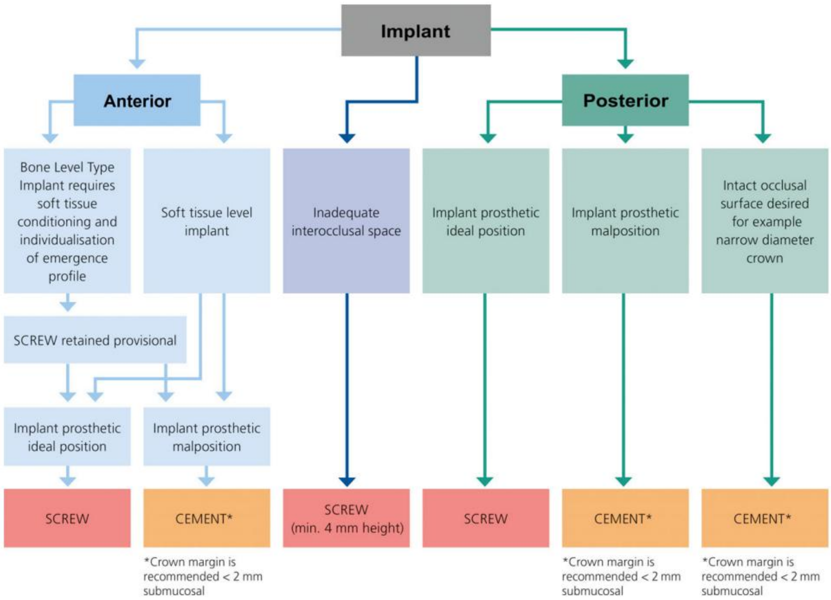
The gingival response is found to be better when using screw-retained crowns since no cement is used. However, if prosthetic retaining screws and abutment screws become loose, granulation tissue accumulates between the prosthesis and the abutment and also between implant and abutment leading to fistulae formation, plaque deposition, and screw fracture. Therefore, it is recommended to retighten the screws in full arch fixed prosthesis every 5 years [49].

THE ‘SCREWMENTABLE’ IMPLANT CROWN

The “screwmentable” implant crown is another possible treatment option that combines the advantages of both cement-retained and screw-retained implant restorations. In the screwmenable implant crown, the abutment and implant crown are cemented extraorally. This can be done by the lab prior to the appointment or chairside.[50]

III. Summary And Conclusion

Meticulous treatment planning and prosthetically driven implant placement should be mandatory for implant therapy. Both retention types have their advantages and limitations. It is therefore the clinician’s responsibility to select the most appropriate method of retention for the individual case [51]. A decision tree is illustrated below. In the anterior region, a)if it’s bone level implant and ideal implant position – screw retained prosthesis is a good option and if it’s not an ideal implant position and bone level implant- cement retained prosthesis. b) if it’s tissue level implant – cement retained prosthesis is recommended. Condition where interocclusal space is less, screw retained restoration of minimum 4 mm height is preferred. In the posterior region, a) implant prosthesis position is ideal – screw retained is preferred b) Implant prosthesis is not ideal – cement retained and if an intact occlusal surface is desired e.g. Narrow diameter crown – cement retained is preferred.



The pathway of decisions in respect of the indication of screw vs. cementation in fixed prosthodontics supporting implants [51].

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