The Significance Of Passive Framework Fit In Implant Prosthodontics: Current Status

Saime Sahin, DDS, PhD,* Murat C. Çehreli, DDS, PhD**

The introduction of osseointegration has dramatically affected the discipline and current perspective of implantology and improved the quality of life of many completely edentulous patients.1–3 Concurrent with the concept, the use of dental implants has successfully expanded for applications in partial edentulism, maxillofacial prosthetics, and orthodontic anchorage.4–10 Recently, early loading of osseointegrated implants has been reported,11 Furthermore, if the clinical objective is to provide a prosthesis at the day of implant surgery, probably the most spectacular improvement has been introduced by the Brånemark Novum System (Nobel Biocare, Göteborg, Sweden) to deliver an implant-supported fixed mandibular prosthesis to a completely edentulous jaw in approximately seven hours.12 Thus it is an undisputed fact that osseointegrated implants are dependable and efficient and have demonstrated an improved success rate over years.

The increased number of clinical applications has led to many scientific investigations that have contributed to an evolution in implant systems, treatment concepts, and techniques used for framework fabrication. During the last three decades, the significance of the biomechanical aspect of implant treatment has been emphasized and safety measures13–20 have been suggested and applied to control the biomechanical load over dental implants.

A rigid connection between osseointegrated implants and a fixed superstructure induces strains in each component exposed to force. The superimposition of functional loads generates additional strains that affect the entire bone-implant-prosthesis assembly. One of the major challenges to a prosthodontist is the delivery of an acceptable prosthesis that will not compromise the longevity of the resultant treatment.

**The Significance Of Passive Fit**

Implant-supported fixed prostheses comprise essentially screw-retained and cement-retained superstructures.21,22 The use of any retention technique necessitates a profound evaluation of a number of significant premises and parameters. Among these, the clinical aspect of passive fit has not been demonstrated, and claims regarding the subject are largely anecdotal. Although the challenge to apply advanced technology to improve framework fit seem promising, this article reviews the clinical significance of passive fit and the factors that affect the final fit of implant-supported frameworks. (Implant Dent 2001;10:85–92) Key Words: screw-retained prosthesis, cement-retained prosthesis, superstructure misfit, passive fit

*Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.
**Research Assistant, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.

ISSN 1056-6163/01/01002-085$3.00
Implant Dentistry
Volume 10 • Number 2
Copyright © 2001 by Lippincott Williams & Wilkins, Inc.
cylinder, frameworks, and veneers have been documented and may be related to poor framework fit. However, there is no longitudinal clinical study that reports implant failure specifically attributed to framework misfit. The vital question then arises as to whether absolute passive framework connection is really essential and if it is a governing factor for implant success. In an excellent review by Taylor et al., one of the major problems was stated as follows: "If it is assumed that misfit is a real problem when dealing with dental implants, 2 questions must be asked. First, what level of misfit is clinically important, beyond which damage is likely to occur? The answer to this question is obviously very complex and probably depends upon such factors as bone quality, length and diameter of implants, and implant surface characteristics. Secondly, assuming that misfit is a concern, how does one measure it in a clinical situation?"

Location, direction, and magnitude of applied loads, and design of the superstructure, and the type and design of the superstructure, and the correct interpretation of the qualitative nature and the quantification of stresses around load-carrying implants is often a challenge because of the inevitable inclusion of several governing factors such as bone density, diameter, length, width, number, location, and macrodesign of dental implants. The problem is probably more perplexing than it seems. For instance, the correct determination of the physiologic tolerance level of an ill-fitting superstructure would require the investigation of the isolated strains in bone, implants, and the prosthesis by empirically testing several superstructures with various degrees of misfit. Accordingly, in a study conducted by Carr and co-workers, screw-retained misfitting superstructures were connected to implants in baboons where it was not possible to distinguish a difference in bone response in two levels of misfit and in the absence of applied occlusal load. One of the reasons for failure was attributed to the possibility that the implant abutment could have absorbed some of the misfit-induced strain and decreased the strain transferred to the implant-bone interface. Assuming that this is true, the isolation of absorbed strains on each component must be provided to ensure the correct interpretation of strains throughout the load-bearing system. This is not currently available.

An acceptable marginal fit of a restoration is not a sign of passive fit. Although there is a consensus that framework misfit causes adverse biologic host response, the clinically acceptable amount of superstructure passivity has not been determined for implant-supported restorations. The only method for determining the actual amount of superstructure passivity is the analysis of the strains on each implant abutment and/or component of the prosthesis before and/or after cementation or screw-fixture. Following such a procedure is certainly time consuming and would require the bonding of a number of strain gauges that also requires the use of sophisticated and expensive equipment. This is definitely not practical, and its inclusion in a routine treatment protocol does not seem rational.

Contemporary prosthodontic treatment for implant-supported prostheses is comprised mostly of derivations and empirical modifications of traditional clinical and laboratory procedures. After following appropriate adjustment procedures, the cement-retained prostheses are accepted to be passive when placed on implant abutments. Although not substantiated by research, this assumption has been introduced as an advantage over screw-retained superstructures and has probably led to the placement of an infinite number of nonpassive prostheses. Clelland and Van Putten have demonstrated that when compared with conventional screw fixation for mandibular fixed prostheses resin luting actually decreases the strains in a bone similar to the placement of an infinite number of nonpassive prostheses. The screw tension introduced in the gold screw joint for the Brånemark System (Nobel Biocare) is 300 μN, the effect of marginal discrepancy is about 150 μm. This situation places a risk on the longevity of the gold screw. The same misfit level also seems to be applicable for most clinical applications. Because the marginal gap of multi-unit castings often approaches several microns, a cast implant-supported multi-unit one-piece fixed prosthesis will surely have wide gaps between the abutment and the prosthesis. Screw tightening causes strains in and around dental implants, and its magnitude is dependent on the amount of misfit. The screw tension introduced in the gold screw joint for the Brånemark System (Nobel Biocare) is measured as approximately 300 N. Distortion of both the superstructure and the implant is observed during the tightening of a screw-retained superstructure. In such cases, the amount of distortion may reach a level such that a 500 μm marginal gap may not be detectable with an explorer. A subtle closure of gaps occurs. Prestresses in the entire system may cause complications associated with cyclic fatigue under continual application of func-
sional loads over time. However, the amount of misfit of a conventional cast superstructure does not induce marginal bone loss over years; a hypothesis that has been put forth regarding a compensating biologic tolerance mechanism. In a retrospective study, Kallus and Bessing have claimed that 236 patients wearing actually misfitting implant-supported prosthesis for at least five years had no signs of loss of osseointegration and that misfit of the superstructures did not affect the maintenance of marginal bone level. It seems that the biologic response for misfit levels between 38 \( \mu m \) and 345 \( \mu m \) is similar. Accordingly, the implant success rate for screw-retained prostheses is high, and, as stated previously, implant failures specifically attributed to nonpassive superstructures have not been documented. Clinical procedures that are followed for framework fit evaluation are empirical, and evaluations are based on direct visualization and tactile sense, leading to uncalibrated (uncontrolled) human evaluation that is undependable.

The fit of a cast framework is supposed to be evaluated in both the laboratory and the patient’s mouth. According to the one-screw test, it is recommended to screw the framework from the most distal abutment and check for possible lifting of the frame. Then, the middle gold screw is placed, and so forth. After placing the gold screws one by one, a final 180 degree turn is performed to reach a torque of 10 Ncm for complete screw seating. If more than a half turn is needed to provide seating of the gold screw, the framework is a misfit and requires further clinical and laboratory work. There are alternative methods for the clinician to check the seating of frameworks. Detection of any marginal gap may be accomplished by using an explorer, a fit-checker, enhanced lighting, or magnification. The detection of a gap is an indication that sectioning and soldering (or welding) are required. Additionally, framework-fit evaluation in the patient includes the subjective determination of tension or pain that also lead to sectioning. Soldering or laser-welding of sectioned prosthetic components does not necessarily provide a passive fit. They do provide an overall decrease in the strains around implants, which may result in an overall decrease in gold screw loosening frequency.

The Measurement of Distortion

The use of a computer numeric controlled milling technique and premachined titanium components for laser-welded framework fabrication facilitates improved marginal fit and seems clinically predictable in comparison with cast frameworks. However, Jent and co-workers also reported that there was a three-dimensional distortion of the gold cylinders ranging between 3 \( \mu m \) and 80 \( \mu m \) and that there was no significant difference between the fit of cast- and computer numeric controlled-milled frameworks and the lack of passive fit. The marginal discrepancy of frameworks fabricated by the All-In-One technique (Nobel Biocare) is around 30 \( \mu m \) (personal verbal communication; Hans Nilson, 1999, Umeå, Sweden). According to Van Roekel, precise passive fit is established if electrical discharge machining is used for framework fabrication. However, the study did not include the method of evaluation of fit.

Measurement of the exact three-dimensional distortion of a framework (the marginal discrepancy) is a difficult task. Achievement of accurate and verifiable measurements can only be provided by following a dependable protocol and using a precise measuring device. Systems used to quantify the three-dimensional framework distortion are the Mylab, University of Washington, three-dimensional photogrammetry, and University of Michigan systems. Additionally, Jent and colleagues have also demonstrated that the photogrammetry technique is valid as an alternative to conventional impressions while following the computer numeric controlled milling technique for framework fabrication and that it could also be used to measure the mucosal topography around dental implants. Among current measurement methods, photogrammetry is the only method that can record data intraorally. Use of the Mylab coordinate measuring machine seems to provide the most accurate results in vitro.

Regardless of which fabrication technique or alloy is used, the distortion of a framework occurs on three planes (\( x \), \( y \), and \( z \)). The distortion is pronounced in the horizontal plane (\( x \) and \( y \)), and it is directly proportional to the increase in width or curvature of the arch. More distortion occurs when using conventional cast or laser-welding of titanium components horizontally instead of vertical welding. Jent and Lie demonstrated that the rate of angular distortion for individual cylinders measured by the photogrammetry method in a cast mandibular full-arch one-piece framework ranged between 11 \( \mu m \) and 181 \( \mu m \). The distortion in the sagittal direction (\( y \) axis) was pronounced. Accordingly, the cylinders exhibited an approximate posterior angulation of 16 \( \mu m \). The angular distortion values recorded for the maxilla ranged between 133 \( \mu m \) and 315 \( \mu m \). A trend for sagittal distortion was also observed.

Effect of Treatment Time on Framework Fit

For tooth-supported multi-unit fixed prostheses, the evaluation of the passivity of a cast restoration is not required. Because of the curvature of the arch and movement of the teeth in the anterior and posterior segments, variable magnitudes and directions may create stresses in long-span prostheses. Research in periodontometry has revealed that natural teeth exhibit buccolingual movement between 56 \( \mu m \) and 108 \( \mu m \) and an intrusion of 28 \( \mu m \) under applied load, which is particularly related to the existence of the periodontal ligament. Because osseointegrated implants are completely surrounded by bone and the interface is nonresilient, minimal movement is observed that is attributed to the deformation of the bone under load. Dental implants and natural teeth follow different patterns to applied loads. The periodontal liga-
ment has a cushioning effect, and natural teeth have the inherent tendency to migrate when overloaded. Implants, on the other hand, distribute the applied load throughout the system and transfer it to the bone. This explains the cause of the intrusion of natural teeth in a tooth-implant-supported fixed prosthesis.\textsuperscript{64,65} When a fixed prostheses is connected to osseointegrated implants, lateral forces are applied that may trigger cortical bone resorption or appear as prosthetic complications after superimposition of functional stresses. This scenario may change according to the treatment protocol followed. Although achievement of a 100\% osseointegrated implant does not seem possible, there is a consensus that 70\% bone-implant contact is capable of bearing \textit{in vivo} functional loads.\textsuperscript{66} The progenitor philosophy for the doctrine of osseointegration was based on a two-stage surgical protocol, and it was extremely important to avoid loading the submerged implants during the healing period. Brånemark\textsuperscript{67} envisaged a healing phase of 0 to 12 months to the stable, resting implant, a remodeling phase of 3 to 18 months after introduction of functional loads, and a steady state after 18 months wherein an equilibrium was established between the forces acting upon the implant and the remodeling capacities of the anchoring bone. However, the success of so-called immediate or early loading and consecutive research\textsuperscript{68–70} have actually revealed that implants may be loaded in a relatively short period of time after installation only in the anterior mandible that is to support a fixed prosthesis. This treatment option emphasizes the fact that the anterior mandible, which is often composed of highly dense bone, has the inherent potential to provide adequate support and initial stability for dental implants that are supposed to bear functional loads early (about one week) after implant placement. It is believed that early-loaded implants are initially stable and do osseointegrate in time (personal communication; Ingvar Ericsson, 1999). The clinical application of the Brånemark Novum System (Nobel Biocare) is comprised of the placement of the majority of the implants (123 of 150) in bone quality 2\textsuperscript{71} provided immediate loading of dental implants. Thus, after three decades of research and experience, the philosophy has evolved into a same-day treatment protocol.\textsuperscript{12} The system may have provided a significant advance in superstructure fit by having the potential of being almost passive in time to provide a compensating micromovement of the implant through applied load by the minimally misfitting superstructure, which may easily be accomplished in seven hours. From a prosthetic aspect, the elimination of an impression and all subsequent steps that are followed for cast superstructures is of utmost importance because the materials and methods used for these procedures affect the final fit of a framework. All components, including the framework, are prefabricated, and implants are installed in accordance with the framework that is provided by the use of a series of accurate surgical guides. Machining tolerance between components is inevitable and may be compensated by features incorporated into the design. The performance of an implant system is directly related to implant design. The implants used in the Novum System are different from the traditional two-stage Brånemark System. If they are not, then the decrease in the number of supporting implants would cause a detrimental increase in induced stresses around the implants, particularly when cantilever loading.\textsuperscript{15,66}

\section*{Outcomes of Current Clinical and Laboratory Techniques}

Each step of the fabrication of a cast framework influences the final fit. A minimal discrepancy (22–100 \textmu m) exists between impression copings and either the prosthetic abutment or the abutment replica. This should be considered when making the final impression and during master cast production.\textsuperscript{72} The impression material\textsuperscript{13,74} and the technique followed\textsuperscript{55,76} affect the final fit of the framework. Dimensional changes related to the use of square impression copings are relatively lower than tapered copings, and it is generally recommended to unite them with a dimensionally stable pattern resin.\textsuperscript{36} The setting expansion of dental stone influences the final fit of frameworks, but it cannot be changed.\textsuperscript{77} Thus, various fabrication techniques have been employed for master cast fabrication. Vigolo and Millstein\textsuperscript{77} have observed that the use of sectioned master casts provides superior fit in comparison to the use of solid casts. There is also a minimal machining tolerance between gold cylinders and abutment replicas that cannot be avoided.\textsuperscript{72}

While fabricating a pattern, two basic aspects should be evaluated. First, the final distortion will definitely be more if wax is used\textsuperscript{37} instead of a resin, which has low polymerization shrinkage.\textsuperscript{36} Second, the design and bulk should provide adequate strength for the framework. However, an increase in the volume of the pattern causes more casting shrinkage, indicating a restriction of the bulk of the pattern.\textsuperscript{37,78} The investment material setting expansion, investment technique, and the type of casted alloy also affect the magnitude of any final discrepancy.\textsuperscript{37,78,79} Although gold alloys have lower casting shrinkage than cobalt-chromium alloys, three-year clinical results of cobalt-chromium frameworks are promising.\textsuperscript{78} One-piece complete-arch frameworks generally require sectioning and soldering (or welding) to improve fit. The determination of the connector that is to be sectioned is completely dependent on the clinical experience of the practitioner; however, steps should be followed for the soldering process that affects the final fit.\textsuperscript{23,37} There is an overall decrease in bone strains around dental implants when superstructures are soldered or laser welded.\textsuperscript{44,51–53}

\section*{Conclusion}

Absolute passive framework fit has not been achieved in the last three decades. There is no consensus but rather a number of suggestions regarding the acceptable level of misfit. In light of current knowledge, although there are claims that pas-
sive fit is a governing factor over the maintenance of osseointegration and implant success, there is a rising opposing trend in relevant literature. The materials and the techniques used for fabricating cast-frameworks are not dimensionally accurate and may require further research and development. Obtaining a passive fit does not seem to be possible and may in fact be unnecessary.

References

40. Balshi TJ. An analysis and management of fractured implants: A clinical
Abstract


SCHLÜSSELWÖRTER: schraubenfixierte Prothese, zementfixierte Prothese, Brückenfehlsitz, passiver Sitz.


ABSTRACTO: Los procedimientos clínicos y de laboratorio empleados para la fabricación de armazones son inadecuados para proporcionar un calce pasivo absoluto para las superestructuras fijas apoyadas por el implante. Mientras que la ocurrencia de algunas complicaciones protéticas se atribuye a la falta de un calce pasivo, su efecto en el éxito de los implantes es cuestionable. No obstante, los resultados clínicos de más aplicaciones de tecnologías avanzadas para mejorar el calce del armazón parecen prometedores. Este trabajo evalúa la importancia clínica del calce pasivo y de los factores que afectan al calce final de los armazones apoyados por implantes.

PALABRAS CLAVES: Prótesis retenida con tornillos, prótesis retenida con cemento, mal calce de la superestructura, calce pasivo.

AUTOR(ES): Saime Sahin, D.D.S., Ph.D.*, Murat C. Çehreli, D.D.S., Ph.D.**. * Profesor, Dep. de Prostodontia, Facultade de Odontología, Universidade de Hacettepe, Ancara, TURQUIA. ** Asistente de Pesquisa, Dep. de Prostodontia, Faculdade de Odontologia, Hacettepe, Ancara, TURQUIA. Correspondências devem ser enviadas a: Murat C. Çehreli, Gaz Mustafa Kemal Bulvari, 61/11 TR 06570 Maltepe, Ancara, TURQUIA. Telefone: +90.312.321.6146, Fax: +90.312.311 3741 e-mail: mcehreli@hotmail.com

SINOPSE: Os procedimentos laboratoriais e clínicos empregados na fabricação de estruturas são inadequados para oferecer um encaixe absolutamente passivo para estruturas fixas suportadas por implantes. Devido ao fato de que a ocorrência de algumas complicações protéticas é atribuída à falta de um encaixe passivo, seu efeito no sucesso dos implantes é questionável. Além disso, os resultados clínicos do aumento de aplicações de tecnologia avançada para aprimorar o encaixe da estrutura se mostram promissores. Este ensaio faz uma revisão da acepção do encaixe passivo e dos fatores que afetam o encaixe final de estruturas suportadas por implante.

PALABRAS-CHAVES: prótese de retenção por parafusos, prótese de retenção por cimento, encaixe de superestrutura imperfeito, encaixe passivo.
インプラント補綴歯科学におけるパッシブ・フレームワーク・フィットの重要性：現状分析

著者：サイメ・サヒン、DDS、PhD*、ムラット・C・クチレリ、DDS、PhD**

概要：臨床・ラボの双方で使われているフレームワーク組立法は、インプラント支持による固定スーパーストラクチャーの完全なパッシブ・フィットの達成には不十分である。補綴に伴う合併症の一部は不完全なパッシブ・フィットに起因するものとされることが多い。これがインプラントの成功に必ずしも悪影響を与えるとは言い切れないものの、最新技術のより多用によって、フレームワークフィットの臨床結果は改善できそうである。本論文はパッシブ・フィットの臨床の重要さと、インプラント支持フレームワークの最終的フィットに影響を与える要因を再確認する。

キーワード：ねじ固定型補綴、セメント固定型補綴、スーパーストラクチャーのミスフィット、パッシブ・フィット

*ハセッテーベ大学（トルコ国アシラ）歯学部補綴歯科学部教授
**ハセッテーベ大学（トルコ国アシラ）歯学部補綴歯科学部研究助手

問い合わせ先：Murat C. Çehreli, Gaz Mustafa Kemal Bulvari, 61/11 TR 06570 Maltepe, Ankara, TURKEY
電話：+90.312.324 6146  ファックス：+90.312.311 3741  E-メール：mcehreli@hotmail.com