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# Intraoperative Impression and Control of Passive Fit in Immediate Loading

# 11

## PASSIVE FIT IN PROSTHETIC STRUCTURES: CRITERIA AND EVALUATION

In modern implant dentistry, several long-term studies have defined the success rate of osseointegrated implant-supported prosthetic rehabilitation,<sup>1,2</sup> which has encouraged the spread of its use in cases of complete and partial edentulism.

In traditional delayed loading implant treatment, after a first phase of osseointegration, failure can occur because of peri-implant infection or failure of the prosthetic structure. Most complications and failures in implant-prosthetic rehabilitation consist of repeated loosening of retention screws, fracture of the veneer material, fracture of retention screws or the metal framework, implant fracture, and resorption of marginal bone up to implant loss. The two main causes of these complications are occlusal overloading and lack of passive fit of the implant-prosthetic connection.<sup>3</sup>

In immediate loading implant treatment, the implant-supported prosthetic rehabilitation aims to restore the anatomical and structural integrity of the stomatognathic system by creating an ideal emergence profile and thereby ensuring the maintenance of the restoration. Progressive implant loading must not interfere

with maturation and remodeling of the surrounding bone tissue.<sup>4</sup>

Osseointegrated implants do not possess the periodontal ligament and thus lack the resiliency of natural teeth that enables them to absorb transversal loads. The lack of a periodontal ligament also means the implant position cannot adapt to an ill-fitting framework. This lack of adaptation means that the forces acting on the implant and the strain created by an implant framework without passive fit produce mechanical stresses acting on the components of the implant-prosthetic connection and the bone-implant interface.<sup>5,6</sup>

Whereas the healing time frame suggested by Brånemark was established on an empirical basis, from 1979<sup>7</sup> until the present day<sup>8-11</sup> many studies have been conducted on immediate loading, with reported success rates ranging from 91.2% to 100%—similar to those achieved with the traditional protocol.

Protection of the bone-implant interface is a factor of primary importance for implant success and survival.<sup>12</sup> An early and excessive load can cause excessive micromovements at the interface that may compromise the initial bone remodeling process<sup>13</sup> and lead to a fibrous repair process rather than osseointegration.<sup>1,14,15</sup>

A crucial prerequisite to achieving osseointegration during the immediate loading protocol is the absence of micromovements of the implants by taking an accurate impression of the implant position and splinting them together rigidly with the provisional prosthesis. Micromovements of less than 150  $\mu\text{m}$  do not interfere with the process of osseointegration and tend to favor secondary stability of the implant. Micromovements of more than 150  $\mu\text{m}$  may cause mobilization of the implant and induce its fibrous integration rather than osseointegration.

The response to implant placement is ruled by two main factors: the self-generating capability of the organism and the functional

stimulation coming from the implant itself.<sup>16</sup> During the first 20 to 40 days after implant insertion, it is necessary to ensure absolute immobility to prevent the osteoid tissue that has just been deposited from evolving in the direction of fibrous tissue.<sup>17,18</sup> Two approaches have been proposed to achieve implant stability: (1) excluding the implant from occlusal function<sup>19</sup> or (2) loading them in a controlled procedure<sup>20</sup> capable of eliminating spatial variation to achieve rigid stability.<sup>21</sup> Immobilization guarantees the first intrinsic osteogenic processes. In the subsequent 40 to 80 days, adequate mechanical stimulation is necessary to sustain and potentiate the processes of bone maturation.<sup>22</sup>

Problems related to passive fit are mostly evident in the following situations:

- In screw-retained prostheses supported by multiple implants, where the retention screws are progressively tightened to compensate for implant-prosthetic misfit of the framework, producing transverse forces and reducing the capacity to absorb and distribute occlusal loads.
- In the same type of prostheses in immediate loading protocols, where the passive framework has to stabilize the implants and favor osseointegration.

In contrast, the cement-retained implant-supported prosthesis is less affected by the strains produced by screw tightening and through the cementing process is able to compensate in part for a lack of passive fit of the prosthetic structure.<sup>23</sup> These tensions are static forces acting on the implant even in the absence of occlusal load, subjecting it and its prosthetic components to continuous stress. Whereas implant-prosthetic misfit produces static forces and thus a constant stress, occlusal loading produces dynamic forces and thus a discontinuous stress.

Several variables directly influence the ability to achieve passive fit in an implant-sup-

ported prosthetic structure: lack of parallelism among implants, large number of implants, and implant arrangement spread widely across the arch. Furthermore, the presence of a cantilever emphasizes the dynamic forces under loading and increases the stresses to which all the biologic and mechanical components are subjected.<sup>24</sup> The ideal length of the distal cantilever, ie, the anteroposterior (A-P) spread, corresponds to one and a half times the perpendicular distance between the most mesial implant and the most distal implant. The length of the extension directly and exponentially influences the forces acting on the distal implant.<sup>24</sup>

Studies have shown that at 5 years ill-fitting fixed screw-retained implant-supported prosthetic reconstructions do not cause resorption of the peri-implant bone tissue greater than what could be hoped for in optimal conditions and thus do not influence implant survival.<sup>25</sup> Other studies show that some degree of misfit is tolerable and does not influence the long-term survival rate of implants, but they also indicate that it does cause numerous prosthetic complications such as repeated screw loosening, fracture of the retention screws, and fracture of the veneer material and metal structures.<sup>3,26</sup>

Different methods have been proposed to evaluate implant-prosthetic misfit clinically in the oral cavity, but they are not simple to apply.<sup>27,28</sup> These are:

- Visual observation where the implant-prosthetic connection is supragingival
- Alternating digital pressure to reveal any movement of the structure<sup>29</sup>
- Tactile exploration by probe<sup>30</sup>
- Radiographic examination<sup>31</sup>
- Use of pressure-revealing paste<sup>32</sup>
- Visual analysis through the “optical comparator”<sup>33</sup>
- The photogrammetric technique<sup>34,35</sup>
- The Periotest (Medizintechnik Gulden) method<sup>36</sup>

- Individual screw-tightening test, which includes fixing one end of the framework to visualize any marginal discrepancy at the opposite end<sup>25</sup>

All of these methods have significant disadvantages such as high subjectivity, insufficient sensitivity, and above all, difficulty in standardizing the method and the data obtained. These disadvantages make such evaluations neither repeatable nor predictable.

### PRODUCTION OF A PROSTHETIC STRUCTURE WITH PASSIVE FIT

To produce a Toronto-Brånemark prosthesis, five to six implants must be positioned at the mandible. The immediate loading protocol requires the implants to be functionalized immediately after placement by inserting the abutments and, at the same time, a provisional prosthetic structure. However, the procedure might present the challenge of fabricating a metal framework that will not produce stresses of any type while being screwed to the supporting implants.

Scientific evidence on the acceptable degree of misfit in implant-supported prosthetics is lacking; estimates vary from  $10^1$  to  $30^{37}$  and as high as  $150\ \mu\text{m}$ .<sup>38</sup> A review of the literature has shown that passive fit of the implant framework is essential to guarantee osseointegration<sup>27,39</sup> and for long-term success of the implant-prosthetic restoration.<sup>28</sup>

In clinical practice, correct positioning of the implants and precise recording of their position are essential to achieving a passive fit of the framework on the implants and in limiting biomechanical loads.<sup>5</sup> There are three fundamental steps to be evaluated in creating an optimal passive fit of the implant framework: (1) the method used to take the impression; (2) the laboratory phase, including the development of the master cast and the construction

of the metal framework; and (3) the method to achieve passive fit indirectly on the cast and/or directly in the mouth.

Different methods are available to the clinician for recording the position of implants: with an individual impression tray, perforated or closed<sup>40,41</sup>; splinting or not splinting the impression copings with resin or dental stone<sup>42</sup>; and using different impression materials such as dental stone, polyether, or silicone.<sup>5,33,43</sup>

The linear contraction of impression materials, which influences the implant-to-implant distance, can vary from 0.03% for polyether to 0.08% with polyvinyl siloxane materials. To reduce this contraction, the use of an individual impression tray is recommended because the smaller the quantity of material, the less contraction it undergoes. It is also advisable to splint the copings with self-curing resin and, in the immediate loading protocol, to use a modified surgical template for recording the implant position directly with self-curing resin.

The expansion of dental stone ranges from 0.08% to 0.2% and may cause distortion of the master cast. This will produce an inaccurate and ill-fitting screw-retained framework for multiple implants.<sup>5,44</sup> Control over this expansion is possible by using low-expansion class 4 dental stone such as GC Fujirock EP (GC Labs); by using precision systems such as Silfradent Cruise 440 (Silfradent), Zeiser System (Giraback Dental) or Pindex (Coltène Whaledent); and by checking the implant position in situ with a verification index. Use of self-curing resin to stabilize the impression copings into a rigid structure compensates for movements caused by contraction of the impression material.<sup>41,42,45-47</sup>

The contraction of the metal framework due to cooling of the metal casting is considered the main factor responsible for the lack of its passive fit to implants.<sup>48-50</sup> This distortion is difficult to quantify and depends on the alloy used, shape and thickness of the framework, and casting technique.<sup>51</sup> Passive casting can be

achieved through different techniques: a slow and careful one-piece casting of controlled-expansion gold alloys with controlled-expansion coating<sup>35</sup>; casting of individual components and secondary soldering<sup>32</sup>; the all-in-one Procera system (Nobel Biocare)<sup>52</sup> or computer-aided design/computer-assisted manufacture (CAD/CAM)<sup>53,54</sup> systems; or Architech PSR (Biomet 3i), CAM StructSURE Precision Milled Bars (Biomet 3i), the electroerosion, the gold galvanic electro-deposition of primary caps subsequently splinted into a secondary structure, and the Cresco precision method (Astra Tech Dental).<sup>21</sup> This latter system entails correcting the distortion by dissecting the framework horizontally and laser welding it to preformed titanium cylinders mounted on implant analogs of the master cast and sectioned in their turn along a plane that is perfectly parallel to the previous one.

### INDIRECT METHODS OF ACHIEVING PASSIVE FIT: AN EXPERIMENTAL STUDY

To achieve prosthetic success, it is essential to determine the parameters on which the rigidity of the bone-implant interface depends and to condition them sufficiently to make osseointegration a predictable result, including with immediate loading protocols. The goal is to produce a prosthetic framework with passive fit that will stabilize the implants without interfering with osseointegration.

An experimental study by the authors analyzed the passive fit of fixed, screw-retained implant frameworks for Toronto-Brånemark hybrid prostheses in an immediate loading protocol.<sup>55</sup> The variable factor in the process of making a passively fitting metal framework was the impression-taking methodology. The clinical implications of achieving passive fit as well as three different impression-taking techniques have been evaluated. In the immediate loading

protocol, the impression is made immediately after implant placement and before definitive suturing of the flaps, using the implant mounting devices as impression transfer copings. The study analyzed passive fit during try-in of the framework and aimed to provide the following clinical evidence: a method for the clinical evaluation of implant-prosthetic fit and a method to take an accurate impression to eliminate implant-prosthetic misfit.

For this research, a steel model was fabricated, representing the position of six implants in the patient's mouth, simulating the clinical situation of a Toronto-Brånemark denture. Six implants were placed to increase the number of marginal gaps. The implants, which have an external hexagonal connection, were arranged in the experimental model with a larger diameter than generally found in clinical conditions to compensate for the greater length and curvature, which may have exacerbated any difficulties of fit of the implant-prosthetic framework.

Impressions were taken on the experimental steel model after the mounting devices that served to transfer the implant position were splinted and stabilized. Three different impression techniques were used, and for each of these, three impressions were made, for a total of nine impressions (FIG 11-1). Each of the impression techniques entailed the use of an individual impression tray made of self-curing resin used both as an intraoperative device (surgical template)—containing all the information about the optimal position of the implants, maxillomandibular vertical dimension, and centric relation—and as an impression tray, by adding an anterior shield to act as a handle.

The first technique (group 1) used the light-curing composite material Tetric Flow (Ivoclar-Vivadent) to splint the transfer devices and the polyether Impregum (3M Espe) as impression material (FIG 11-2A). The second technique (group 2) used the self-curing acrylic resin Pattern Resin LS (GC Labs) to splint the transfer devices and the polyether Impregum

as impression material (FIG 11-2B). The third technique (group 3) simply used the self-curing acrylic resin Pattern Resin LS to splint the transfer devices without any impression material (FIG 11-2C).

From each impression a master cast was developed from GC Fujirock EP extra-hard dental stone for a total of nine casts. On each of the nine casts, a titanium framework was fabricated with the lost-wax casting technique and subsequently passive fit was achieved on the respective dental stone master cast using the Cresco precision method, for a total of nine implant-supported prosthetic frameworks.

Titanium screws were used to tighten the implant-supported prosthetic framework to the implant analogs in the master cast and to the implants in the experimental model. The pitch of the retention screws was 350  $\mu\text{m}$ ; consequently, each degree of rotation of the screw corresponded to a vertical excursion of approximately 1  $\mu\text{m}$ .

Each of the nine implant-prosthetic frameworks was evaluated with regard to its passive fit on the respective master cast (FIG 11-3A) and on the experimental steel model (FIG 11-3B) for a total of 18 evaluations (SEE FIG 11-1). The fit was evaluated using the OsseoCare screw tightening system (Nobel Biocare) preset to a maximum torque of 20 Ncm. Both on the master cast and on the experimental steel model, the retention screws were tightened and the torque recorded in a clockwise direction from left to right, with the position of the arch in vivo being used as reference. The graphic reproduction of the tightening torque of each screw shows curves having the torque value (Ncm) on the y-axis and the angle of rotation of the screw on the x-axis. The measurement process itself began and ended with the engine motion. The last 240 degrees of the rotation, corresponding to the last two-thirds of the rotation of the screw, were visualized. The passive fit of the implant framework was evaluated through a mathematic analysis of the data obtained from the screw

trial. The data collected were analyzed in their graphic representation and as numeric data at the statistical level.

The research also evaluated the passive fit of the implant-supported prosthetic framework directly in vivo on a patient through each clinical phase via the same method as the experimental study. The treatment plan included a maxillary full-arch removable denture and a mandibular fixed full-arch Toronto-Brånemark hybrid prosthesis supported by five interforaminal implants. The mandibular fixed provisional prosthesis, fabricated with titanium framework and resin prosthetic teeth, was delivered 36 hours after surgery.

The impression was taken with a dedicated device acting initially as a surgical template with detachable handle fabricated on the basis of a duplicate of the patient's provisional removable complete denture to guarantee the precise reproduction of the centric occlusion and of the vertical dimension. The implant position was recorded by splinting and stabilizing the implant mounting devices using Pattern Resin LS. The master cast resulting from this procedure was used to fabricate both the provisional prosthesis, inserted 36 hours after implant surgery, and the definitive prosthesis, placed 4 months after surgery and immediate loading. The screw-tightening procedures of both the provisional and the definitive hybrid prostheses were evaluated on the cast and in the oral cavity, again through both graphic and numeric analyses.

The reference graph shows that the tightening of a single screw, a passive structure, can be subdivided into three basic phases (FIG 11-4A). For approximately 200 of the last 240 degrees of rotation during the initial tightening phase, the torque maintained a low value, under 2 Ncm, which expresses the resistance of the retention screws due to friction with the internal screw thread of the implant. In the second phase, from approximately 200 to 220 degrees of rotation, the retention screw is subjected to

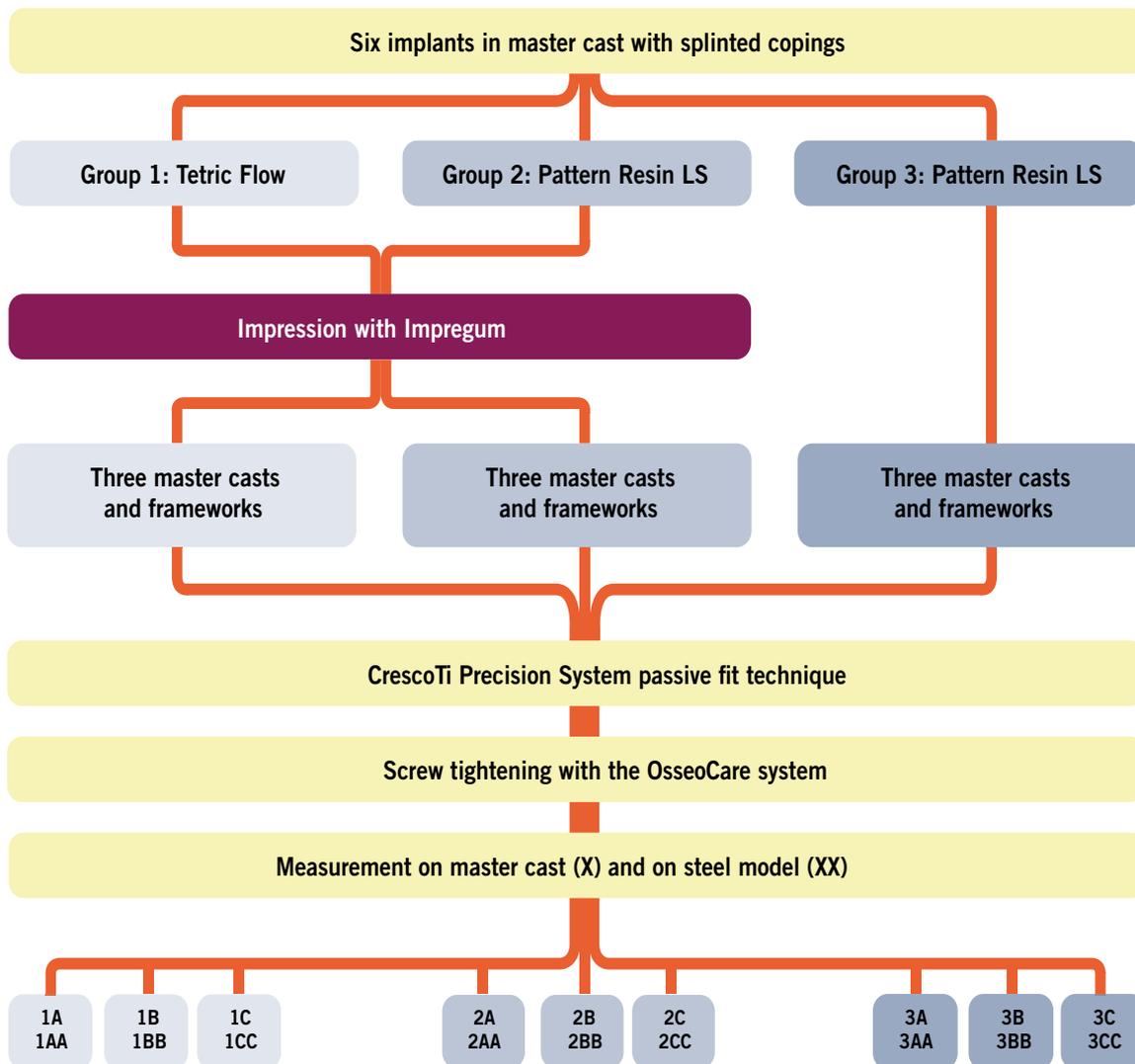


Fig 11-1 → Algorithm showing experimental design of study.

elastic deformation generated by close contact between the surfaces. In the third phase, from approximately 220 to 240 degrees of rotation, the screw is loaded up to the maximum preset torque value of 20 Ncm, which coincides with the plastic deformation and final tightening of the screw.

The following graphs show the values of resistance to screw tightening of the frameworks measured on the master cast (1A) and on the experimental steel model (2CC and

3AA) [FIGS 11-4B TO 11-4D]. The values are measured for the six screws of each framework and are expressed in Ncm. The last 240 degrees of rotation—which correspond to two-thirds of a full rotation and to approximately 240  $\mu\text{m}$  of vertical excursion of the screw (which has a pitch of approximately 360  $\mu\text{m}$ )—are considered. The numeric values are analyzed at 100, 190, 220, and 240 degrees of rotation of the screw.



2A	
2B	2C
3A	3B

Fig 11-2 → (a) In group 1, the polyether impression was taken after splinting the transfer copings with light-cured composite resin. (b) In group 2, the impression was taken after splinting the copings with self-curing acrylic resin and polyether. (c) Group 3 simply entailed the use of self-curing acrylic resin.

Fig 11-3 → Evaluation of the nine implant-supported prosthetic frameworks was performed both on the dental stone master cast (a) and on the experimental steel model (b).



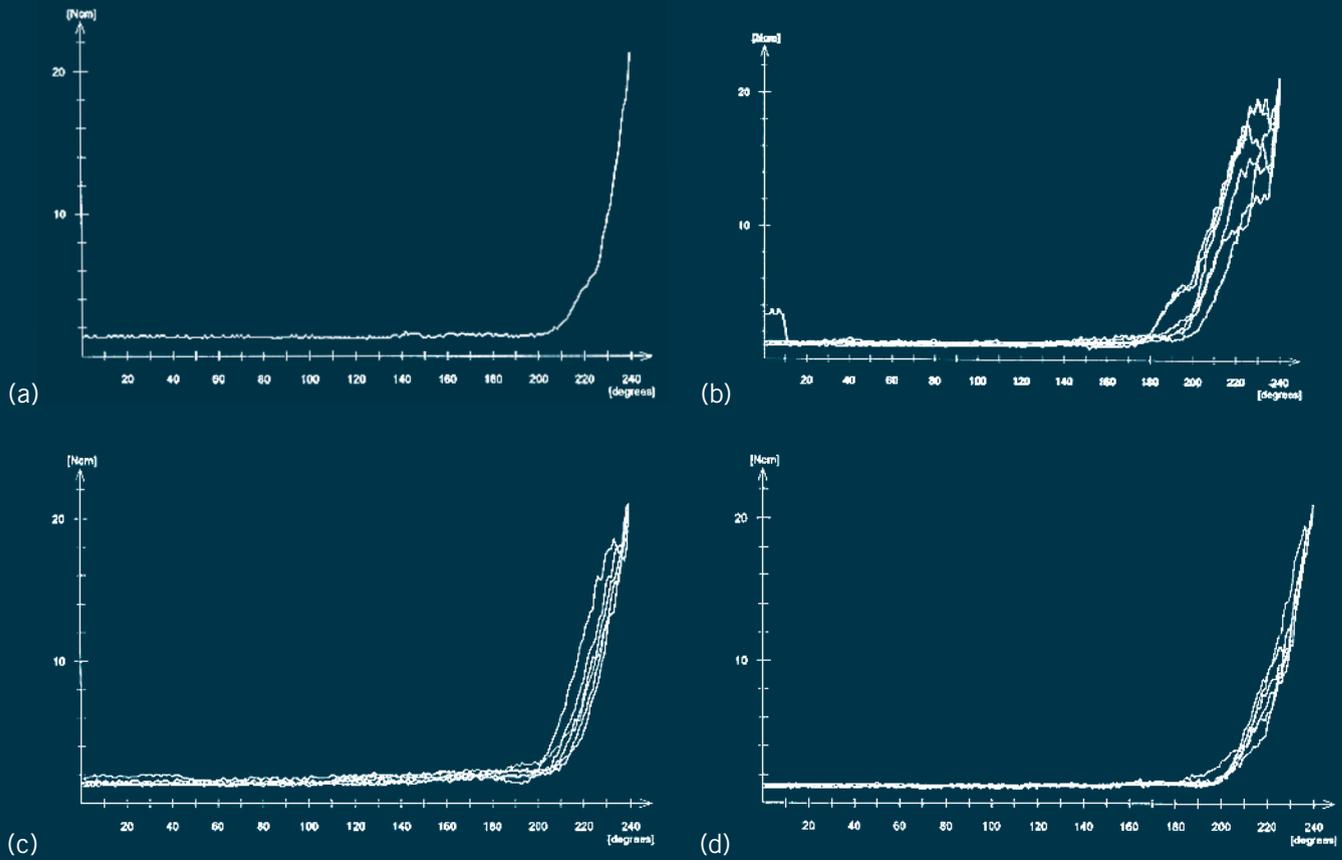


Fig 11-4 → Graphic representation of the screw-tightening torque values. (a) The single screw is by definition passive. (b) Framework 1A shows a clear discrepancy in the final phase of tightening on the dental stone cast. (c) Framework 2CC shows a good passive fit on the steel model. (d) Framework 3AA presents a better passive fit on the steel model than on the dental stone master cast.

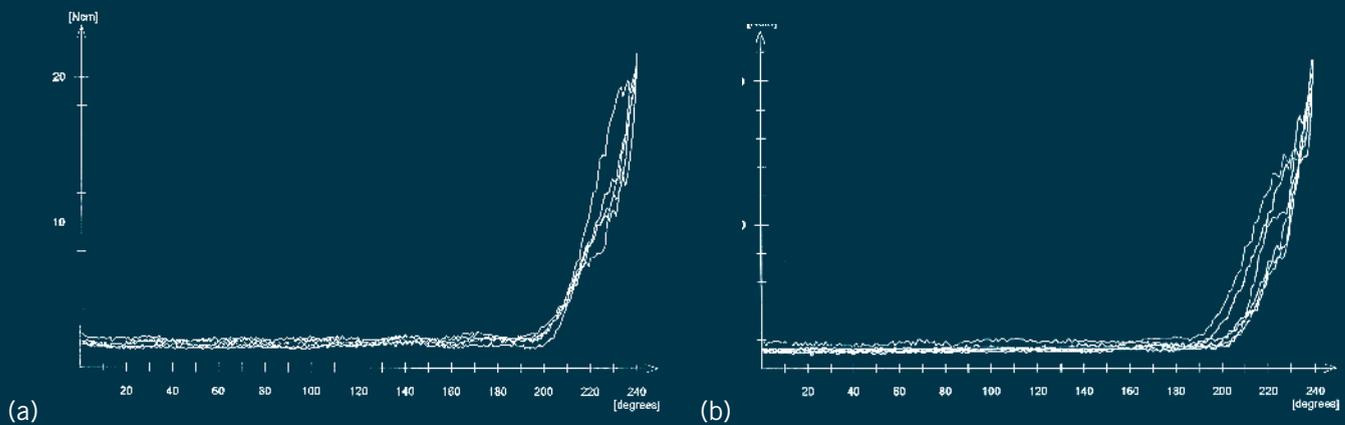


Fig 11-5 → (a) The provisional immediate framework shows a good passive fit. (b) The definitive framework presents a degree of passive fit with data showing an increase in tension in the tightening phases after 180 degrees of rotation.

Fig 11-6 → Mean torque and standard deviation of the measurements on the experimental steel model for each of the three experimental groups at 100, 190, 220, and 240 degrees of rotation.

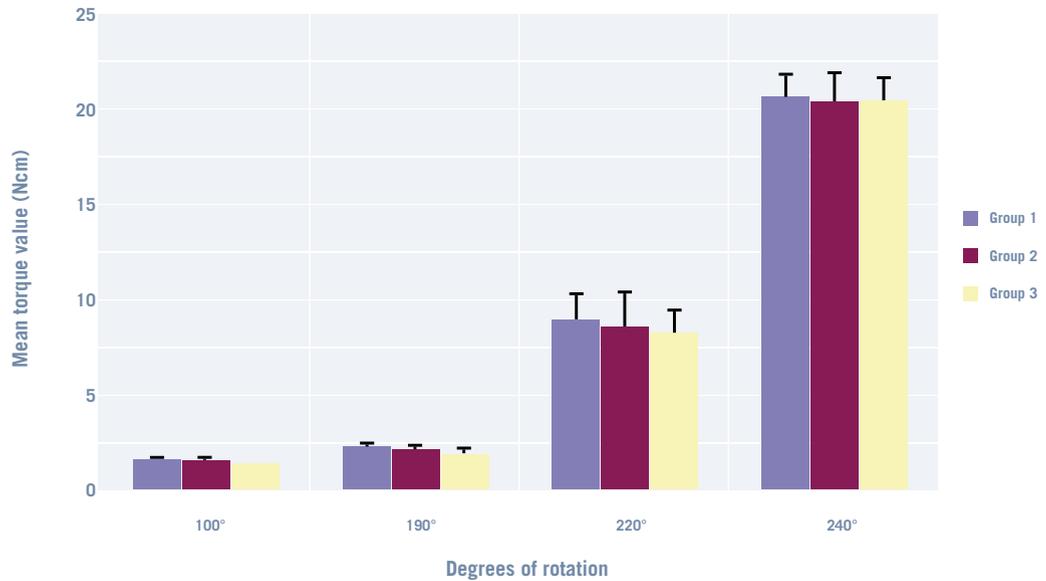


Figure 11-5 shows the torque values for the provisional immediately loaded hybrid prosthesis and for the definitive prosthetic framework in the clinical phase of the research. In both cases, measurements have been made on the master cast and in the mouth.

Figure 11-6 shows the mean torque value and standard deviation of the measurements on the experimental steel model for each of the three test groups at 100, 190, 220, and 240 degrees of rotation. The graphic representation of the result shows that the three methods are very similar (Fig 11-7).

With regard to the impressions in which the transfer devices were splinted with the light-curing composite Tetric Flow combined with the use of the impression material Impregum (group 1), the graphs indicate a substantially passive fit. The frameworks 1A and 1B show better passive fit on the experimental steel model than on the dental stone master cast (SEE FIG 11-4B); the framework 1C presents similar values both on the dental stone master cast and on the experimental steel model.

The impressions with the transfer devices splinted with the self-curing resin (Pattern Resin LS) combined with the use of Impregum impression material (group 2) show three tracings, 2A, 2B, and 2CC, that are substantially passive both on the stone master cast and on the experimental steel model (SEE FIG 11-4C). In group 3, where the transfer devices were splinted only with self-curing resin, (Pattern Resin LS), the tracing 3AA shows a better passive fit on the experimental steel model than on the dental stone master cast (SEE FIG 11-4D), and the frameworks 3B and 3C show similar values both on the stone master cast and on the experimental steel model, with less steep curves of screw tightening than in the previous cases.

In the patient, the immediate framework shows a good passive fit both on the dental stone cast and in the oral cavity, with torque values below 2.2 Ncm up to 190 degrees of rotation (SEE FIG 11-5A). The definitive framework shows an excellent passive fit on the master cast with less favorable data measured in situ, showing an increasing tension in the screw tightening after 180 degrees of rotation (SEE FIG 11-5B).

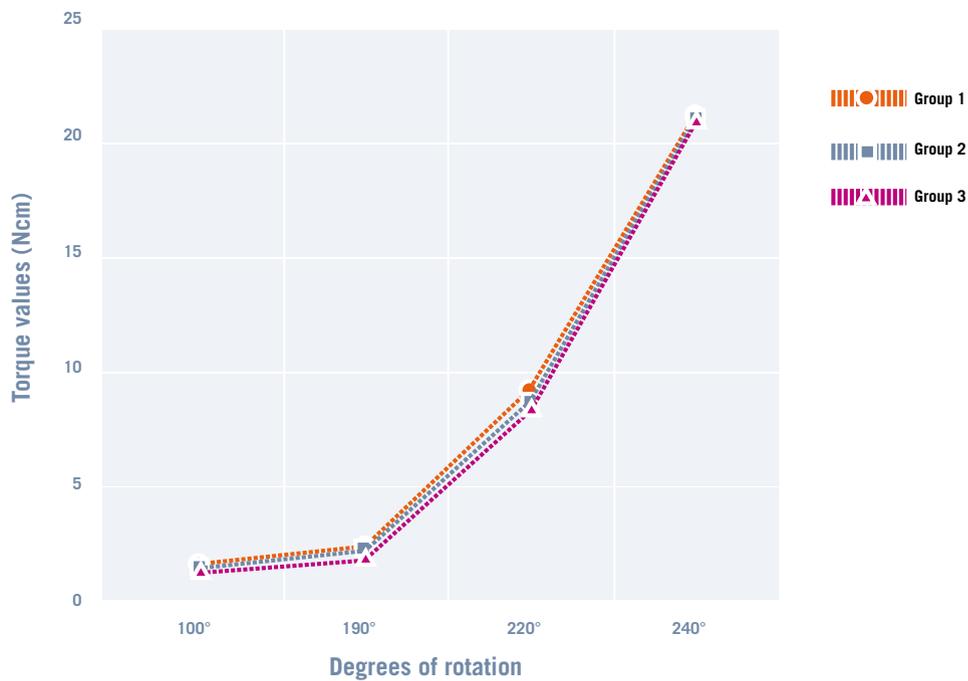


Fig 11-7 → Measurements for the three methods nearly overlap.

The tracings made on the dental stone casts are all substantially passive, demonstrating that with regard to the passive fit of frameworks on the working master cast, predictable results can be obtained with the titanium one-piece casting method combined with the passive fit system CrescoTiPrecision System.<sup>21</sup>

Tracings made on the experimental steel model overlap substantially with slight discrepancies in favor of group 3, which were more accentuated in the final phase of screw tightening (SEE FIGS 11-6 AND 11-7).

At the current state of knowledge, a degree of misfit in the range 60 to 90  $\mu\text{m}$  is considered clinically passive<sup>25</sup>. This corresponds to a range from 60 to 90 degrees of rotation.

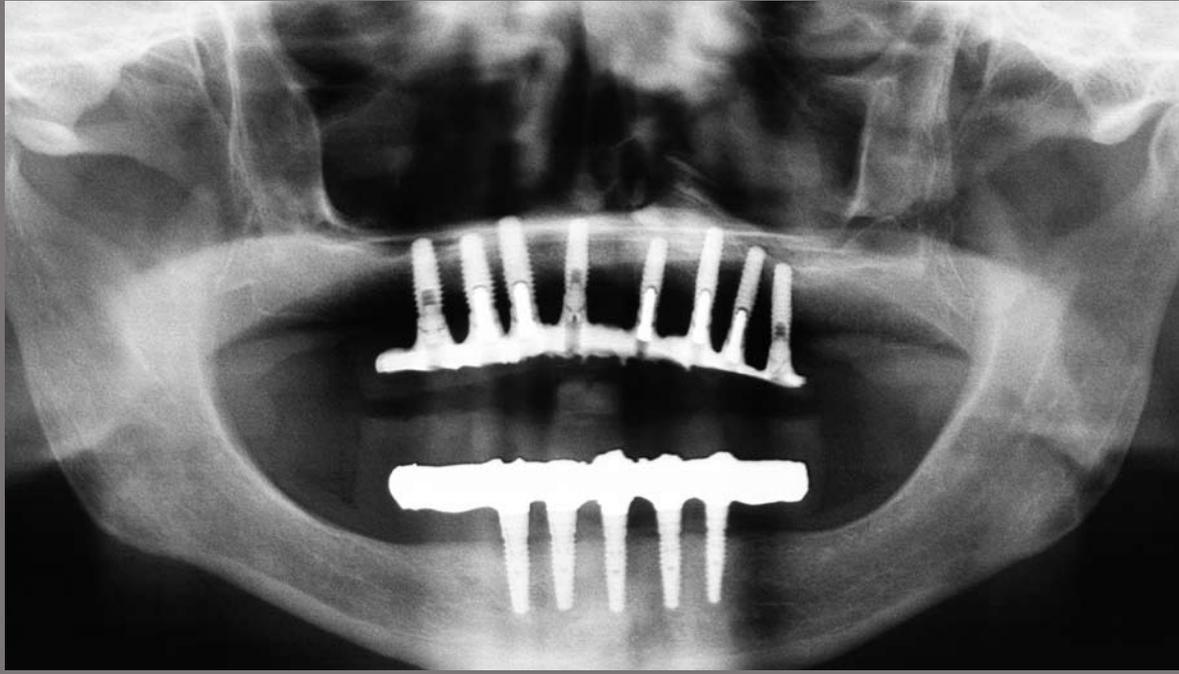
The experimental method used in group 3, which corresponds to the one used on the patient in vivo, showed uniform results with a mean marginal misfit below 40  $\mu\text{m}$  and thus a good degree of passive fit. These results are in agreement with immediate loading protocols, which require that micromovements be limited

and that the implant be stabilized. In groups 1 and 2, the marginal misfit is clinically acceptable, being in the range of 20 to 80  $\mu\text{m}$ .

The screw-tightening sequence of the prosthetic framework, selected to amplify any misfit, had no influence on the final result.

## CONCLUSIONS

The passive fit of the screw-retained implant-supported prosthetic framework is essential to achieving and maintaining osseointegration over time, especially in immediate loading protocols, where the primary stability of the implants must be guaranteed.<sup>3-6</sup> It is essential to achieve passive fit at each step of fabrication of the screw-retained implant-supported immediate prosthesis. This depends on a perfect knowledge of the materials used and the correct execution of each step. By carefully taking the impression, the clinician guarantees that the implant position will be correctly transferred.<sup>40-44</sup> Through appropriate fabrication methods, the laboratory technician ensures



8A

8B

Fig 11-8 → Positioning of the two implant-supported prosthetic frameworks with passive fit restores the integrity of the anatomy and the function of the stomatognathic system, guaranteeing osseointegration of the implants over time. (a) Final panoramic radiograph. (b) Extraoral view of definitive prostheses.

the passive fit of the framework on the working cast, which will guarantee the success of the rehabilitation over time (FIG 11-8).

The quantitative evaluation of the resistance to screw tightening through the OsseoCare screw tightening system is a simple method, scientifically validated and clinically useful, for analyzing the passive fit of the implant-supported prosthetic framework. The system makes it possible to tighten the prosthetic structure with a preset torque value and to record the resistance to screw tightening as well as the rotational dislocation of the retention screws. The alternative methods present significant disadvantages because they are highly subjective and not sufficiently sensitive (alternating digital pressure, exploration by probes, Periotest); they make it difficult to standardize the data obtained (radiographic examination, pressure revealing paste, individual screw tightening test); or they carry high costs and are difficult to employ at the same time (“optical comparator,” three-dimensional photogrammetry).<sup>27,28</sup>

The results achieved in the experimental study indicate three methods to take the impression that are substantially very similar in terms of results and that are clinically reliable and predictable. The encouraging results achieved in the group in which the transfer devices have been splinted only with self-curing resin—also used for the *in vivo* evaluation—and its ease of performance, especially in immediate loading protocols, mean that this method is clinically valid and applicable.

The literature suggests how to detect any problems of inadequate passive fit of implant-supported prosthetic structures. These include pain on screw tightening, repeated loosening of retention screws, repeated fracture of esthetic coatings or retention screws, and bone resorption beyond the first screw thread of the implant in the early months of loading.

## REFERENCES

1. Adell R, Lekholm U, Rockler B, et al. A 15 year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Surg* 1981;10:387–441.
2. Lindquist LW. Prosthetic rehabilitation of the edentulous mandible. A longitudinal study of treatment with tissue-integrated fixed prostheses. *Swed Dent J Suppl* 1987;48:1-39.
3. Kohavi D. Complication in tissue integrated prostheses components: Clinical and mechanical evaluation. *J Oral Rehabil* 1993;20:413–422.
4. Aparicio C. A new method for achieving passive fit of an interim restoration supported by Brånemark implants: A technical note. *Int J Oral Maxillofac Implants* 1995;10:614–618.
5. Lorenzoni M, Perti C, Penkner K, Polansky R, Sedaj B, Wegscheider WA. Comparison of the transfer precision of three different impression materials in combination with transfer caps for the Frialit-2 system. *J Oral Rehabil* 2000;27:629–638.
6. Weinberg LA. The biomechanics of force distribution in implant-supported prostheses. *Int J Oral Maxillofac Implants* 1993;8:19–31.
7. Ledermann PD. Stegprothetische versorgung des zahnlosen Unterkiefers mit Hilfe plasmabeschichteten Titanschraubimplantaten. *Dtsch Zahnarztl Zeitung* 1979;34:907–909.
8. Chiapasco M, Gatti C, Rossi E, Haefliger W, Markwalder TH. Implant-retained mandibular overdentures with immediate loading: A retrospective multicenter study on 226 consecutive cases. *Clin Oral Implants Res* 1997;8:48–57.
9. Testori T, Del Fabbro M, Szumkler-Moncler S, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. *Int J Oral Maxillofac Implants* 2003;18:544–551.
10. Testori T, Del Fabbro M, Galli F, Francetti L, Taschieri S, Weinstein R. Immediate occlusal loading the same day or the day after implant placement: Comparison of 2 different time frames in total edentulous lower jaws. *J Oral Implantol* 2004;30:307–313.
11. Testori T, Meltzer A, Del Fabbro M, et al. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw. A multicenter prospective study. *Clin Oral Implants Res* 2004;15:278–284.
12. Adell R, Lekholm V, Rockler B, et al. Marginal tissue reactions at osseointegrated titanium fixtures (I). A 3-year longitudinal prospective study. *Int J Oral Maxillofac Surg* 1986;15:39–52.
13. Adell R. Regeneration of the periodontium: An experimental study in dogs. *Scand J Plast Reconstr Surg Suppl* 1974;11:1–177.
14. Adell R. An overview of the Brånemark osseointegration method comparing total and partial edentulism results. *Z Stomatol* 1993;90:289–301.

15. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term effect of currently used dental implants: A review and proposed criteria for success. *Int J Oral Maxillofac Implants* 1996;1:11–25.
16. Castman E. *Principi Biomeccanici di Fissazione*. Bologna: Edizioni Aulo Goggi, 1983.
17. Aspenberg P, Goodman S, Toksvig-Larsen S, Ryd L, Albrektsson T. Intermittent micromotion inhibits bone ingrowth. *Acta Orthop Scand* 1992;63:141–145.
18. Brunski JB, Skalak R. Biomechanics of osseointegration and dental prostheses. In: Naert I, Van Steenberghe D, Worthington P (eds). *Osseointegration in Oral Rehabilitation: An Introductory Textbook*. Chicago: Quintessence, 1999:133–156.
19. Brånemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 1977;16:1–132.
20. Babbush CA, Kent JN, Misiek DJ. Titanium plasma-sprayed screw implants for the reconstruction of the edentulous mandible. *J Oral Maxillofac Surg* 1986;44:274–282.
21. Hellden LB, Derand T. Description and evaluation of a simplified method to achieve passive fit between cast titanium frameworks and implants. *Int J Oral Maxillofac Implants* 1998;13:190–196.
22. Bianchi A. *Implantologia e Impianto-Protesi*. Torino: Utet, 1999:326–331.
23. Tripton PA. Maximizing aesthetics, fit, and maintenance of the full-arch implant-supported porcelain-fused-to-metal restoration. *Pract Proced Aesthet Dent* 2002;14:395–400.
24. Kunavisarut C, Lag LA, Stoner BR, Felton DA. Finite element analysis on dental implant-supported prosthesis without passive fit. *J Prosthodont* 2002;11:30–40.
25. Jemt T, Book K. Prosthesis misfit and marginal bone loss in edentulous implant patients. *Int J Maxillofac Implants* 1996;11:620–625.
26. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. *Int J Oral Maxillofac Implants* 1994;9:169–178.
27. Wicks RA, deRijk WG, Windeler AS. An evaluation of fit in osseointegrated implant components using torque/turn analysis. *J Prosthodont* 1994;3:206–212.
28. Kan JYK, Rungchaerassang K, Bohsali K, et al. Clinical method for evaluating implant framework fit. *J Prosthet Dent* 1999;81:7–13.
29. Henry PJ. An alternative method for the production of accurate casts and occlusal records in the osseointegrated implant rehabilitation. *J Prosthet Dent* 1987;58(6):694–697.
30. Yanase RT, Binon PP, Jemt T, Gulbransen HJ, Parel S. Current issues forum. How do you test a cast framework for a full-arch fixed implant-supported prosthesis? *Int J Oral Maxillofac Implants* 1994;9:469–474.
31. Murphy WM, Absi EG, Gregory MC, William KR. A prospective 5-year study of two cast framework alloys for implant-supported mandibular prostheses. *Int J Prosthodont* 2002;15:133–138.
32. Goll GE. Production of accurately fitting full-arch implant frameworks. Part I. Clinical procedures. *J Prosthet Dent* 1991;66:377–384.
33. Vigolo P, Millstein PL. Evaluation of master cast techniques for multiple abutment implant prostheses. *Int J Oral Maxillofac Implants* 1993;8:439–446.
34. Lie A, Jemt T. Photogrammetric measurements of implant positions. Description of a technique to determine to the fit between implants and superstructures. *Clin Oral Implants Res* 1994;5:30–36.
35. Jemt T, Lie A. Accuracy of implant-supported prostheses in the edentulous jaw. Analysis of precision of fit between cast gold-alloy frameworks and master casts by means of a three-dimensional photogrammetric technique. *Clin Oral Implants Res* 1995;6:172–180.
36. May KB, Lang BR, Lang BE, Wang RF. Periotest method: Implant-supported framework fit evaluation in vivo. *J Prosthet Dent* 1998;79:648–657.
37. Klineberg IJ, Murray GM. Design of superstructure for osseointegrated fixtures. *Swed Dent J Suppl* 1985;28:63–69.
38. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: A study of treatment from the time of prosthesis placement to the first annual checkup. *Int J Oral Maxillofac Implants* 1991;6:270–276.
39. Aparicio C. A new method to routinely achieve passive fit of ceramometal prostheses over Brånemark osseointegrated implants: A two-year report. *Int J Periodontics Restorative Dent* 1994;14:404–419.
40. Carr AB. A comparison of impression techniques for a five-implant mandibular model. *Int J Oral Maxillofac Implants* 1991;4:448–455.
41. Assif D, Fenton A, Zarb G, Schmitt A. Comparative accuracy of implant impression procedures. *Int J Periodontics Restorative Dent* 1992;12:112–121.
42. Assif D, Nissan J, Varsano I, Singer A. Accuracy of implant impression splinted techniques: Effect of splinting material. *Int J Oral Maxillofac Implants* 1999;14:885–888.
43. Spector MR, Donovan TE, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. *J Prosthet Dent* 1990;63:444–447.
44. Barrett MG, deBijk WG, Burgess JO. The accuracy of six impression techniques for osseointegrated implants. *J Prosthodont* 1993;2:75–82.
45. Zarb GA. Clinical application of osseointegration. An introduction. *Swed Dent J Suppl* 1985;28:7–9.
46. Watanabe F, Uno I, Hata Y, Neuendorff G, Kirsch A. Analysis of stress distribution in a screw-retained implant prostheses. *Int J Oral Maxillofac Implants* 2000;15:209–218.
47. Vigolo P, Majzoub Z, Cordioli G. Evaluation of accuracy of three techniques used for multiple implant abutment impression. *J Prosthet Dent* 2003;89:186–192.

48. Blackman R, Barghi N, Tran C. Dimensional changes in casting titanium removable partial denture frameworks. *J Prosthet Dent* 1991;65:309–315.
49. White GE. *Osseointegrated Dental Technology*. London: Quintessence, 1993:61–94.
50. Tan KB, Rubenstein JE, Nichols JI, Yuodelis RA. Three-dimensional analysis of the casting accuracy of one-piece osseointegrated implant-retained prostheses. *Int J Prosthodont* 1993;6:346–363.
51. Brunski JB. Influence of biomechanical factors at the bone-biomaterial interface. In: Davies JE (ed). *The Bone-Biomaterial Interface*. Toronto: University of Toronto, 1991:391–404.
52. Takahashi T, Gunne J. Fit of implant frameworks: An in vitro comparison between the fabrication techniques. *J Prosthet Dent* 2003;89:256–260.
53. Jemt T, Back T, Petersson A. A precision of CNC milled titanium frameworks for implant treatment in the edentulous jaw. *Int J Prosthodont* 1999;12:209–215.
54. Ortrop A, Jemt T, Back T, Tord J. Comparison of precision of fit between cast and CNC-milled titanium implant frameworks for the edentulous mandible. *Int J Prosthodont* 2003;16:194–200.
55. Franchini I, Rossi MC, Arioli E, et al. Valutazione della passivazione delle sovrastrutture implantari per protesi ibride fisse nel carico immediato. Studio sperimentale. *Implantologia Orale* 2005;4:9–24.