A Simplified Method to Assess Precision of Fit Between Framework and Supporting Implants: A Preliminary Study

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Purpose: *To present a simplified method for assessment of precision of fit between screw-retained frameworks and supporting implants in clinical situations.* ***Materials and Methods:*** *Torque-angle signature analysis is a method for analysis of tension within a joint. The OsseoCare device developed by Nobel Biocare was utilized for the tests. Three titanium frameworks were fabricated on the same master cast according to 3 different methods: (1) 1-piece casting, (2) the CNC (computer numeric controlled) method, and (3) the CTiP (Cresco Ti Precision) method. These frameworks were used to test the device and indirectly the application of the torque-angle signature analysis technology.* ***Results:*** *The frameworks fabricated according to the CNC and CTiP methods demonstrated OsseoCare tracings similar to the reference models of passively fitting joints, while the 1-piece cast framework did not.* ***Conclusion:*** *According to this pilot study, the OsseoCare device and torque-angle signature analysis proved to be feasible for clinical assessment of fit between frameworks and supporting implants.* Int J Oral Maxillofac Implants 2007;22:831–838

Key words: *assessment of fit, dental implants, titanium frameworks, torque-angle signature analysis*

The precision of fit between a framework (superstructure) and the supporting implants is difficult to assess clinically. Various methods have been suggested, but none have gained full acceptance as an accurate standard test.[1] Inspection using a single tightened screw in 1 distal site while observing gaps between the remaining implants and framework still seems to be the most common method for evaluation of misfit. This method can be used in the laboratory, but it is not of the same value intraorally, where the metal contact areas are mostly located subgingivally. Complicated techniques for assessment and measurement of misfit have been presented[2–4]; however, a method suitable for clinical use has not been found. An easy and objective method for assessment of fit in the laboratory as well as in the clinic is therefore desirable.

So-called torque-angle signature analysis is commonly used within the industry to analyze the clamping of joints (ie, the precision of fit between surfaces). Torque-angle signature analysis provides a practical technique for evaluation of the actual clamp force achieved by a fastener installation process. This analysis involves comparing plots of torque versus angle as the fastener is installed or uninstalled. These curves are mainly studied in the elastic tightening region where the fastener has not gone beyond yield. A typical torque-angle tightening curve (Fig 1) consists first of a nonlinear aligning zone, where the fastener aligns parts and draws them together. Next is the elastic clamping zone, where the joint has been stabilized, the parts have been drawn together, and the fastener is snugging up the joint. This portion of the curve is a straight line

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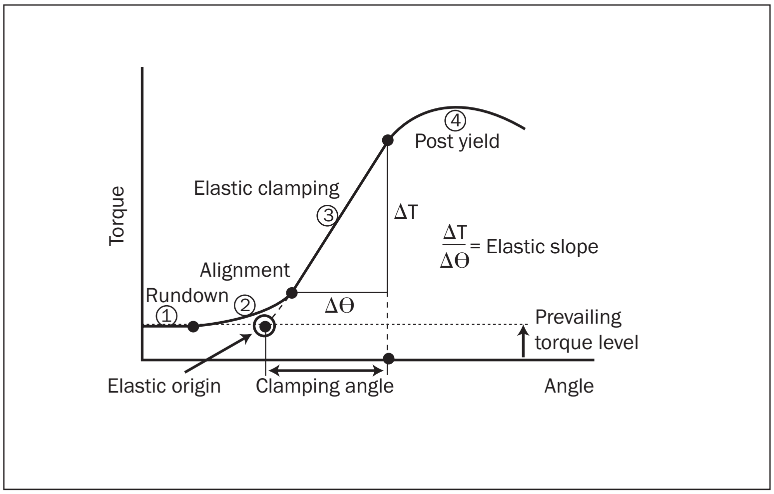

Fig 1 Torque-angle signature analysis. Reprinted with permission of RS Technologies.[5]

or constant slope. Once torquing has been stopped in the elastic clamping zone, a line tangent to the straight line portion of the curve can be projected backward. The point where the projection line strikes zero torque—or the line of a prevailing torque—is called the elastic origin. If the angle of turn is measured from the elastic origin to the point where torquing was stopped in the elastic clamping zone, it will be found that the tension on the joint is directly proportional to that angle of turn. The compression of the parts and stretching of the fastener occurs in a linear fashion from the projected elastic origin.

When the fastener is taken beyond the yield point, the added tension after yield is the angle relative to the straight line elastic clamping portion to the maximum torque point and is not proportional to the overall angle of turn.[6–8]

The torque-angle signature analysis might be used for an objective assessment of the fit between a framework and implant analogs or implants. Nobel Biocare (Göteborg, Sweden) developed and commercialized the OsseoCare device. This device was originally intended to monitor bone resistance/quality during the surgical placement of implants. In the authors' opinion the OsseoCare device could be used to monitor screw-retained implant prostheses with torque-angle signature analysis when screwing in the framework.

The objective of this study was to evaluate whether the OsseoCare device can be used as a reliable and objective tool for the assessment of the precision of fit of implant prostheses in the dental laboratory and in the clinic. A comparative study of the fit between implants and frameworks fabricated according to 3 different methods was utilized for the evaluation of the method.

MATERIALS AND METHODS

The OsseoCare Device

The OsseoCare device includes a computerized motor to which a special handpiece is connected.[9] The handpiece can be used for the insertion of implants into the bone but also for tightening the framework/superstructure retention screws. The motor can be programmed for a specific preset torque. The machine registers the screw-tightening torque and the ramping up of the force during the last 240 degrees of screw tightening. A plot of the screw tightening torque (Ncm) versus the angle of screwing (in degrees) is shown on a screen and also downloaded to a computer using manufacturer-provided software (MCRead v.28085; Nobel Biocare). Figure 2a illustrates the torque-angle signature of a passively fitting joint. After an initial plateau where the torque is needed only to overcome the friction between external and internal threads, the torque starts to increase and finally becomes linear. The initial nonlinear part of the curve is due to the alignment and adjustment of the nonperfect joint (eg, surface asperities), while the linear part corresponds to the elastic elongation of the joint. The intersection of the tangent to the linear zone with the zero-torque axis (ie, the line of the starting prevailing torque level) gives the elastic origin. The angle of turn (clamping angle) measured from the elastic origin to the point of the preset torque in the elastic clamping zone is directly proportional to the tension on the joint. Figure 2b illustrates a case of a joint where the fit was poor. The linear zone of the elastic clamping was not reached before the predetermined torque limit of 20 Ncm. This means that most of the torque was necessary to align and adjust the corre-

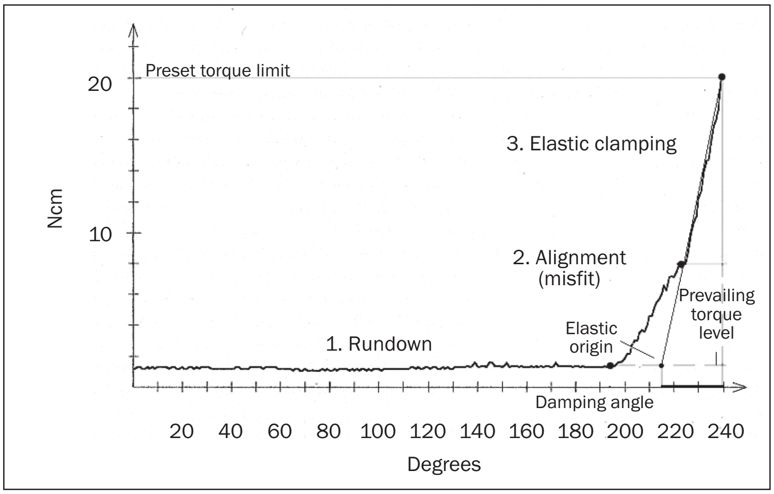

Fig 2a OsseoCare tracing of a well-fitting joint.

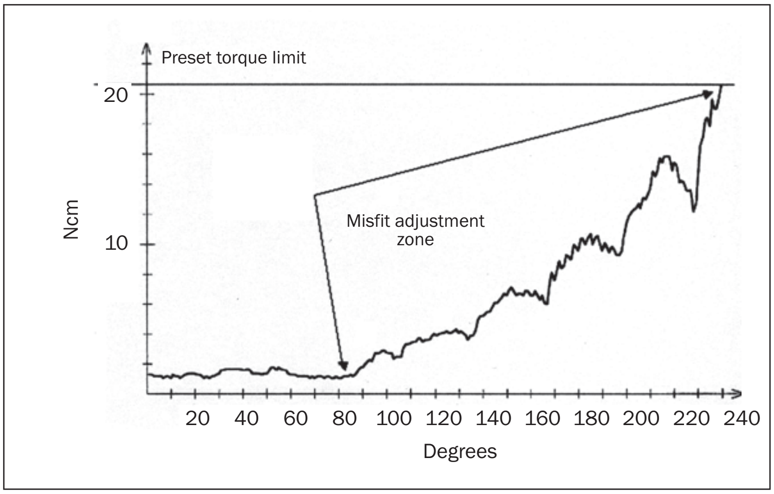

Fig 2b OsseoCare tracing of a joint where the fit between the components was poor.

sponding parts of the joint (ie, to address the joint misfit). The lack of an elastic clamping zone means that the actual pre-tension (or preload) in the retention screw was very low.

Clinical Procedure and Master Cast Fabrication

Five Brånemark standard implants (diameter = 3.75 mm; length = 13 mm; Nobel Biocare) were placed anteriorly (between the mental foramina) in the edentulous mandible of a 65-year-old male patient. The implants were submerged for 4 months. Four weeks after healing abutment connection surgery, an impression was made at "implant level" using a custom open tray, pickup type copings splinted with orthodontic wire, and autopolymerizing resin (Pattern Resin LS; GC Corporation, Tokyo, Japan) and polyether elastomers (Impregum-Permadyne Penta; 3M ESPE, Seefeld, Germany). The implant analogs were mounted by hand, and a stone master cast was fabricated (Fujirock EP Type IV, W/P = 0.2; GC Europe, Leuven, Belgium). The pickup copings were then splinted together with precision resin to obtain a "resin verification jig." This procedure was performed step by step to let the resin polymerize without deformation. The jig was used to check the accuracy of the cast.

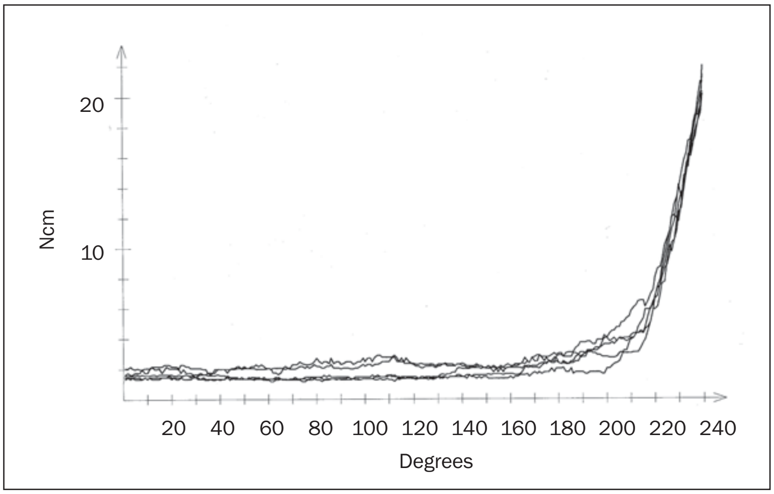

Fig 3a Torque-angle signatures of machined abutments screw-tightened on implant analogs.

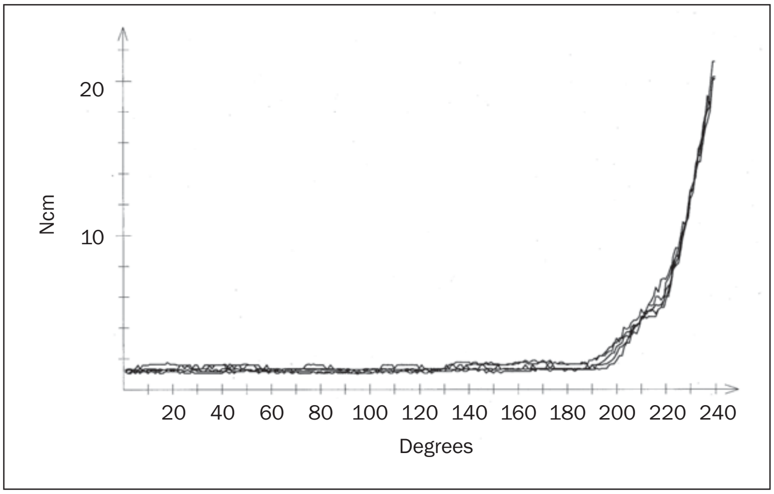

Fig 3b Torque-angle signatures of screws tightened on implant analogs without any abutment or framework.

Frameworks

Three titanium full-arch fixed prosthesis frameworks for screw retention were fabricated on the master cast according to 3 different technologies.

1. One-piece casting of the framework followed by sectioning. The segments were reassembled by laser welding using an Orotic 2000 unidirectional laser (Orotic, Verona, Italy) at 250 A current, 2.5 ms pulse duration, and 1.0 mm spot size at 1.1 Hz spot frequency. The framework tested in this study was arbitrarily divided into 2 segments. Clinical good fit (alternate finger pressure) was apparently achieved on the master cast.
2. The CNC (computer numeric controlled) milling technology developed by Nobel Biocare.[10,11] The framework was milled from a solid titanium piece by a CNC machine.
3. The CrescoTi Precision method (CTiP; CrescoTi Systems, Kristianstad, Sweden). This method uses a conventional approach to framework fabrication. Correction of distortion is achieved by horizontal sectioning of the framework, followed by the use of a laser welding technique to reassemble the superstructure to new titanium cylinders mounted on implant analogs in the master cast. The method has been described elsewhere.[12,13]

Assessment of Fit

Each framework was first screw-tightened to implant analogs of the master cast, and OsseoCare recordings were performed. After removal from the master cast, each framework was similarly tightened to the implants in the oral cavity again to make OsseoCare recordings. The preset torque was 20 Ncm. Fifteen identical retention screws were used for screw attachment of the frameworks. The torque-angle signature of each of the 5 retention screws used per framework was monitored during the screw tightening procedure. The order by which the screws were tightened

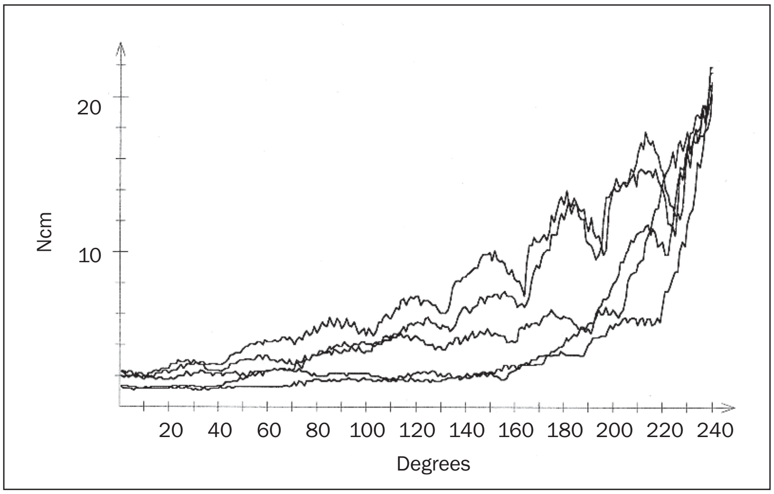

Fig 4a Torque-angle signatures of the 1-piece cast framework screw-attached to implant analogs.

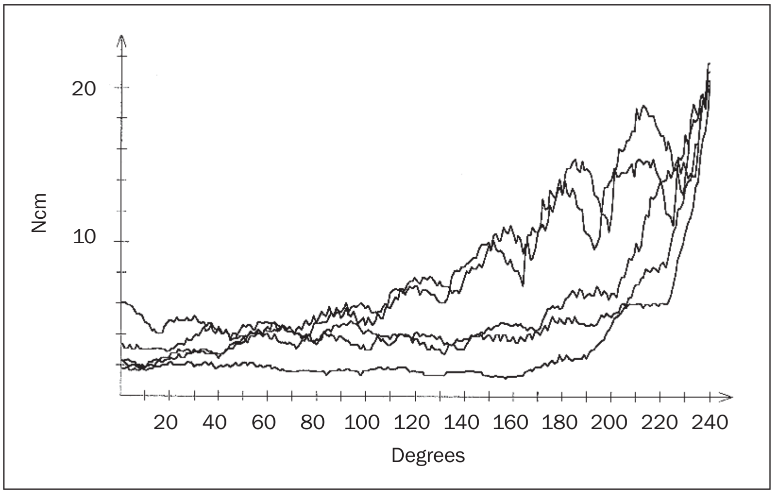

Fig 4b Torque-angle signatures of the 1-piece cast framework screw-attached in the oral cavity.

followed a predetermined protocol. A reference model of good joint fit was created by recording the screw tightening of 5 machined abutments (Brånemark System; Nobel Biocare) on implant analogs of the master cast (Fig 3).

Figure 3b shows a graph of the same 5 screws tightened on implant analogs alone without any type of abutment or framework. The 2 graphs show similar torque-angle signatures.

RESULTS

The torque-angle signature analysis of the 1-piece cast framework (Figs 4a and 4b) indicated a lack of acceptable fit with both implant analogs and implants in the mouth. Most tracings, in conformity with torque-angle signature analysis, exhibited a wide alignment zone with neither a running nor elastic clamping zone. The more or less identical appearance of the graphs obtained from the measurements in the laboratory and the clinic signifies that the impression and master cast fabrication were accurate. This was also verified by the implant positioning index.

The corresponding appearances of the graphs in Figs 5a and 5b and their similitude with the reference curves of Figs 3a and 3b demonstrate the precision of fit of the passivated framework fabricated according to the CNC method. Similar torque-angle signatures were demonstrated for the framework fabricated according to the CTiP method (Figs 6a and 6b). Relatively homogeneous OsseoCare curve tracings were observed for all plots for the frameworks created using these 2 methods. Each curve exhibited a running zone, a short alignment zone, and an elastic clamping zone straight to the preset torque limit. The clamping angle was about 20 degrees.

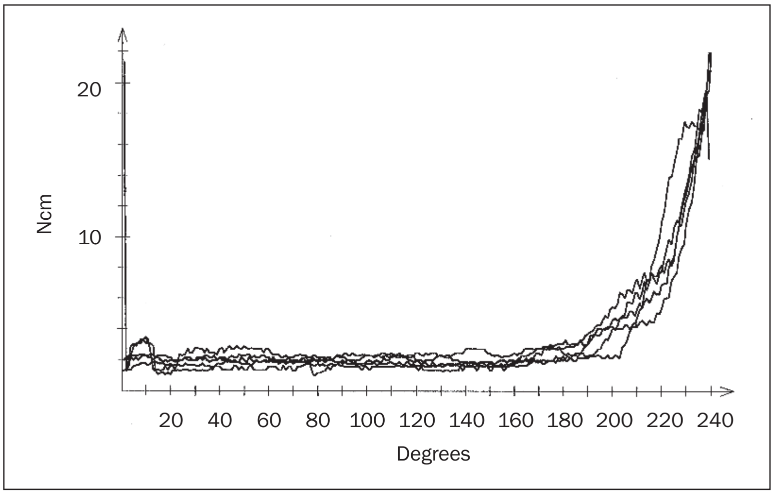

Fig 5a Torque-angle signatures of the CNC framework, screw-attached to implant analogs.

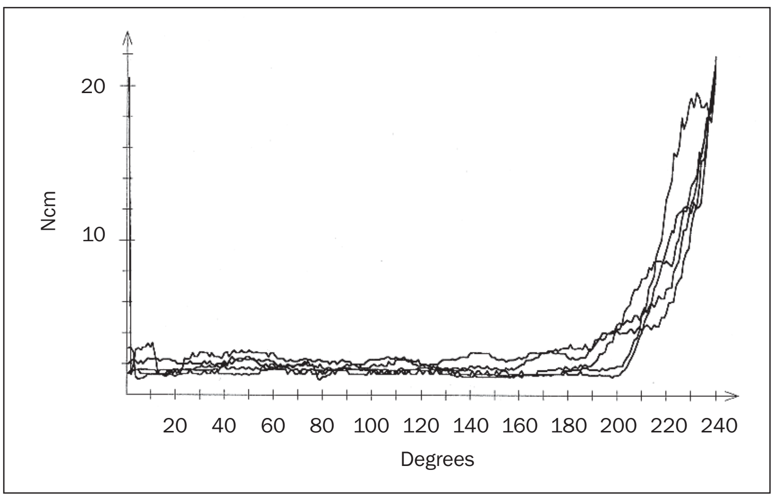

Fig 5b Torque-angle signatures of the CNC framework, screw-attached in the oral cavity.

DISCUSSION

It is unclear whether screw or cement retention is best for the restoration of dental implants. Those who prefer screw retention point to retrievability as a significant advantage. It certainly is a significant advantage in specific clinical situations; it facilitates treatment of peri-implantitis, repair of mechanical complications, and checking of implant stability. The need for a simple method to control the presence of passive fit is more obvious for screw-retained than for cement-retained superstructures.[13–15] The cement compensates for misfit between the superstructure and the abutment-implant assembly, thereby reducing stress forces that otherwise could be transmitted to the implant-bone interface. In contrast, uncontrolled stress and strains are transmitted to the peri-implant bone, the implant components, and the framework during and after the tightening of retention screws if the superstructure does not fit passively on nonresilient supporting implants. Screw-retained prostheses are associated with the potential for screw loosening or fracture.[16] It is generally admitted that the passive fit of a framework will decrease or eliminate such problems.[17] It is well-known within the industry in general (and among professionals in the dental laboratory field in particular) that casting processes can suffer from dimensional imperfections (ie, that the cast, after cooling, does not perfectly reflect the geometry of the mold). This happens for various reasons; it is difficult to compensate perfectly for the shrinking of the material. Dental casting of superstructure is no exception.[18] Augthun et al,[19] for example, demonstrated that spruing technique had an influence on the final geometry. Thus, it seems essential to have access to superstructure fabrication technologies that enable passive fit. In addition there is an obvious need for a method to ensure that passive fit obtained in the laboratory also exists in the mouth (ie, to control that the implant positions in the master cast are identical with the situation in the mouth). If these require-

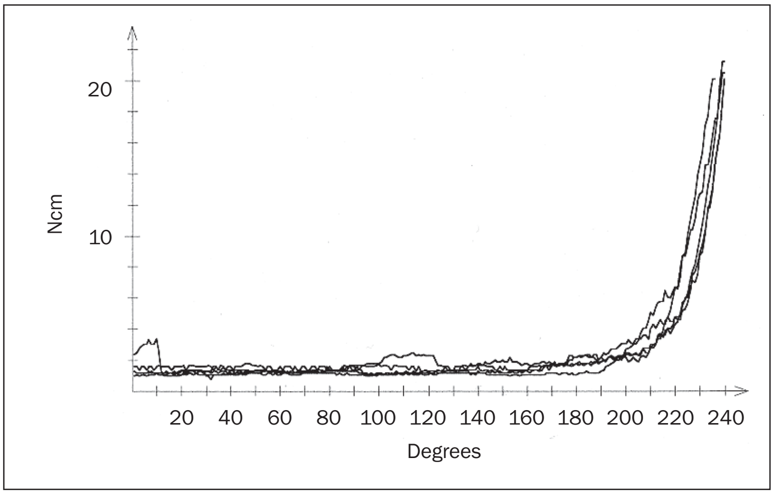

Fig 6a Torque-angle signatures of the CTiP framework, screw-attached to implant analogs.

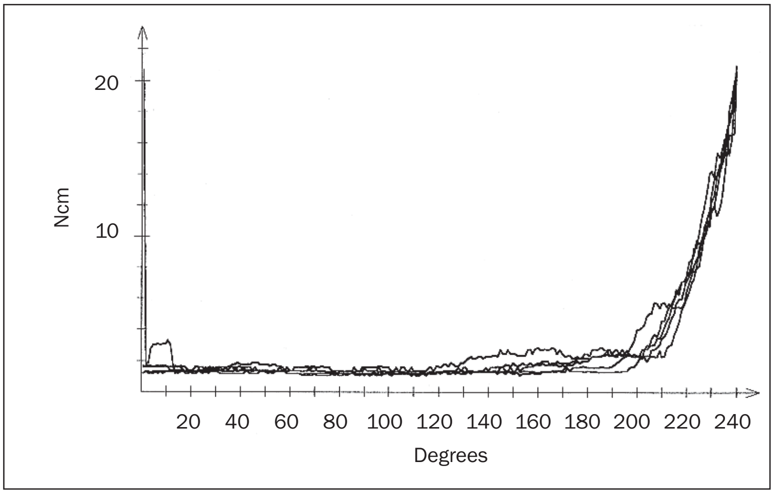

Fig 6b Torque-angle signatures of the CTiP framework, screw-attached in the oral cavity.

ments cannot be fulfilled, the appropriateness screw retention is questionable.

Furthermore, the geometry of a mechanical joint is never perfect. Misfits and surface asperities are accommodated during tightening. In critical industries, especially where vibration loosening or fatigue fractures may have dramatic consequences (eg, the automobile or aerospace industries), proper control of the tightening of joints is a necessity. Torque-angle signature analysis is used in such industries to verify the clamping of a joint. The present authors suggest the use of the Nobel Biocare OsseoCare device for this purpose during the tightening of dental restoration.

Graphs from the superstructures passivated according to the CNC method or the CTiP methods were similar to the tracings of reference models of good-fitting joint. This means that the tension obtained at the preset torque value was optimal for the tensile strength of the joint. However, the tracings of the nonpassivated superstructure displayed nonlinear behavior and were different from the reference curves because of the amount of adjustment that was necessary. Correct tension could not be reached in the joints before the preset torque limit. The stability of the joint was thus reduced, which would result in clinical problems. The results from the present preliminary study suggest that torque-angle analysis could complement existing methods for fabrication and clinical evaluation of passively fitting superstructures.

CONCLUSION

A method is needed to determine whether passive fit of screw-retained implant superstructures obtained in the laboratory also exists in the mouth. Torque-angle signature analysis supports the hypothesis that passive fit is a prerequisite for a stable and long-lasting screwed joint. Based on this pilot study, the authors suggest using the OsseoCare device for clinical control of passive fit between frameworks/superstructures and implants.

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