Screw Joint Stability in Conventional and Abutment-Free Implant-Supported Fixed Restorations

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Purpose: Procera Implant Bridges (PIBs) do not engage supporting implant shoulders and are fixed using comparably long retention screws. The aim of this in vitro clinical study was to determine the detorque values in PIBs and conventionally fabricated fixed dental prostheses (FDPs). ***Materials and Methods:*** Two groups of screw-retained implant-supported three-unit FDPs (n = 10) were fabricated by means of conventional casting or computer-aided design/computer-assisted manufacture to fit an in vitro situation with two implants. Following fixation, the restorations were subjected to masticatory simulation (100,000 cycles, 100 N) and subsequent detorquing of the retention screws. In the clinical part, a total of 10 patients received PIB restorations in the premolar/molar region that were detorqued after 2, 4, and 6 months. One-sample *t* tests adjusted for multiple testing by the Bonferroni-Holm method were applied for statistical analysis based on percentage detorque values ($\alpha = .05$). ***Results:*** 60% of the initial torque values were maintained in screws directly retaining restorations, while the abutment screws used in the conventional restorations showed detorque levels in the range of 80%. No significant difference in detorque levels between screws retaining PIBs and conventional FDPs could be detected ($P = .5186$). The abutment screws showed significantly greater detorque values compared with screws directly retaining restorations ($P = .0002$; $P = .0000$). In vivo, a significant increase in detorque values ranging from 21.64 Ncm after 2 months to 27.81 Ncm after 6 months was recorded. ***Conclusion:*** Prosthetic screws retaining implant-supported FDPs show torque loss during the initial period of service. Retightening reduces the amount of future torque loss. Int J Prosthodont 2016;29:142–146. doi: 10.11607/ijp.4458

Using screw retention for implant-supported fixed dental prostheses (FDPs) offers the advantage of retrievability[1] and avoids the risk of cement-related peri-implant inflammation.[2] However, loosening of retention screws[3,4] has been reported as a clinically relevant problem with an incidence of 6.7% after 5 years.[5] To maximize mechanical stability at the prosthetic interface, implant manufacturers have developed force-fit and form-fit components.[4,6] To benefit from these features, prefabricated implant components have been advocated for achieving maximum precision of fit and longevity in conventional restorations.

Besides providing a multitude of restorative options, computer-aided design/computer-assisted manufacture (CAD/CAM) fabrication techniques for implant-supported restorations have been repeatedly shown to achieve unprecedented levels of fit.[1,7,8] Given that the antirotational features of dental implants can hardly be reproduced with sufficient levels of precision,[9] few CAD/CAM systems offer the possibility of fabricating screw-retained restorations such as Procera Implant Bridges (PIBs) (Nobel Biocare). Such restorations have flat-on-flat prosthetic interfaces that do not take advantage of the implant shoulders' retentive features.[10]

Therefore, it was the goal of this study to compare the removal torque levels of retention screws in conventionally fabricated FDPs and PIBs following masticatory simulation.[11] Additionally, removal torque values in 10 patients restored using PIBs were repeatedly measured.

Materials and Methods

Part I: In Vitro

A polyurethane model duplicating an existing patient situation with two implants placed in the region of a mandibular left first premolar and first molar (Standard Plus Implants, 4.1 mm diameter, 10-mm bone sink depth, Straumann) was fabricated. Using the implant manufacturer's transfer components

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(RN impression cap, RN synOcta positioning cylinder, Straumann) in combination with polyether impression material (Impregum, 3M Espe) and custom-made trays (Palatray XL, Heraeus Kulzer), 20 pickup impressions were made and master casts with individual dies containing the implant analogs were poured in type IV stone (FujiRock, GC Germany).

Following manufacturer-recommended protocols, 10 screw-retained three-unit FDPs were waxed using the implant manufacturer's burn-out plastic copings and cast in high noble metal-fused-to-ceramics alloy (Jensen Expert, Jensen). For standardization purposes, one restoration resembling a mandibular left first premolar and molar as retainers and a mandibular second premolar as pontic, was fabricated and subsequently duplicated using a silicone mold (Silaplast, Detax). All conventional restorations were based on the implant manufacturer's abutments for screw-retained restorations (synOcta screw-retained abutments, Straumann).

Similarly, patterns were obtained for the remaining 10 master casts, which served as a basis for the fabrication of CAD/CAM restorations. Starting from scanning the master casts and patterns, all fabrication steps for the CAD/CAM restorations were carried out by Nobel Biocare. Identical designs were chosen for all restorations with respect to overall dimensions, shape, and connector design, and 10 frameworks were fabricated from titanium (PIB, Nobel Biocare). These restorations could be fixed directly on the implant shoulders without placing abutments.

Prior to fixation of the restorations on the polyurethane model, visual and tactile evaluation using magnifying glasses and a dental explorer was performed to ensure a clinically acceptable fit.[1,8,10] The conventional restorations were fixed on the abutments with occlusal screws (Straumann AG) with a torque of 15 Ncm, while the abutments were mounted with a torque of 35 Ncm. The CAD/CAM restorations were mounted directly on the implant shoulders using the corresponding retention screws (Nobel Biocare) with a torque of 35 Ncm. A surgical motor (Elcomed, W&H) allowing for active torque measurements was used in all cases.

With a restoration mounted on the implants, the polyurethane model was positioned in the water bath of a masticatory simulator (Kausimulator, Hädrich Elektrohandwerksbetrieb) at an angle of 135 degrees in relation to the long axis of the implants and cyclic loading of the specimens was performed for 100,000 cycles[11] at 100 N (2 seconds of loading followed by 1 second of unloading) at a constant water temperature of 37°C.[12–14] Following loading, the restorations were removed from the implants and the removal torque needed was measured (Fig 1).[15–18]

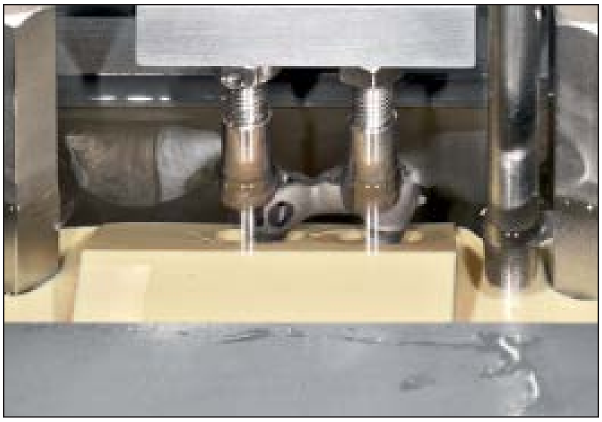

Fig 1 Sample of a Procera Implant Bridge directly fixed on the shoulders of two supporting implants and mounted in the water bath of a masticatory simulator at an angle of 135 degrees in relation to the long axis of the implants.

Part II: In Vivo

Ethics commission approval (medical faculty, University of Erlangen-Nuremberg, Project 296_13B) was obtained prior to starting the in vivo part of the study. After informed consent was obtained, a total of 10 patients were enrolled in a private practice setting (Figs 2a to 2d). All patients had been treatment planned to receive two implants (Replace CC, Nobel Biocare) in the premolar or molar region supporting a PIB (Nobel Biocare) directly fixed on the implant shoulders using the corresponding retention screws, applied with a torque of 35 Ncm (Elcomed, W&H). The substructures of all restorations were made from titanium onto which all-ceramic crowns (IPS e.max, Ivoclar Vivadent) were bonded with an adhesive resin cement (Multilink, Ivoclar Vivadent) following pretreatment of the ceramic surfaces with hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent) and a silane coupling agent (Monobond Plus, Ivoclar Vivadent).

The patients were scheduled for recalls after 2, 4, and 6 months following delivery of the FDPs. At the recall appointment, the restorations were removed from the implants. The torque needed for removal was measured[15–18] (Elcomed, W&H), the implants were cleaned with 0.2% chlorhexidine solution (Chlorhexamed, GlaxoSmithKline), and the restorations were fixed on the implants again. During this phase, the screw access holes were filled with a foam pellet and light-curing temporary filling material (Clip, Voco). As part of the final recall session, new retention screws were used to mount the restorations on the implant shoulders and the screw access holes were restored with foam pellets and composite resin (Tetric Evo Ceram, Ivoclar Vivadent).

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Fig 2a Clinical situation of two bone-level implants used to support a three-unit FDP.

Fig 2b Sample of a screw-retained Procera Implant Bridge made from titanium onto which a ceramic veneer was bonded adhesively.

Fig 2c Clinical situation of a three-unit Procera Implant Bridge supported by two implants in the area of the first premolar and first molar.

Fig 2d Periapical radiograph showing two implants directly supporting a screw-retained Procera Implant Bridge.

Table 1 Mean (Standard Deviation) Detorque Values Measured in Vitro

Restoration type and recommended tightening torque (Ncm)		Premolar	Molar	Total
Conventional restoration	synOcta abutment (35)	27.45 (3.44)	28.58 (4.10)	28.08 (3.76)
	occlusal screw (15)	9.47 (2.51)	8.69 (2.38)	9.08 (2.41)
PIB (35)		20.21 (5.1)	20.19 (2.89)	20.20 (4.08)

PIB = Procera Implant Bridge.

Table 2 Mean (Standard Deviation) In Vitro Detorque Values Given as Percentage of the Tightening Torque Used

Restoration type and recommended tightening torque (Ncm)		Premolar	Molar	Total
Conventional restoration	synOcta abutment (35)	78.30 (9.90)	81.54 (11.70)	80.10 (10.75)
	occlusal screw (15)	63.13 (16.72)	57.96 (15.94)	60.55 (16.12)
PIB (35)			57.57 (8.27)	57.65 (11.65)

PIB = Procera Implant Bridge.

Table 3 Statistical Comparisons Between the Different Screw Types Based on the Percentage Detorque Values Measured In Vitro at the Premolar and Molar Positions[1]

	Occlusal screw	PIB
synOcta abutment	.0002	.0000
Occlusal screw		.5186

[1]One-sample *t* tests, *P* values adjusted for multiple testing by the Bonferroni-Holm method.
PIB = Procera Implant Bridge.

Statistical Analysis

Based on the percentage detorque values[19,20] measured in vitro at the premolar and molar positions, one-sample *t* tests adjusted for multiple testing by the Bonferroni-Holm method were performed for comparing screw joint stability between the two restoration types investigated. Pairwise comparisons of in vivo detorque values measured after 2, 4, and 6 months following delivery of the restorations were performed using the same test method. The level of significance was set at $\alpha = .05$ for all comparisons conducted.

Results

Part I: In Vitro

Following masticatory simulation, all screw types considered showed lower detorque values as compared with the torque levels applied during tightening (Table 1). In the conventional restorations, the occlusal screws tightened with 15 Ncm showed mean detorque values of 9.08 Ncm while the abutments tightened with 35 Ncm required a torque of 28.08 Ncm to loosen the abutment screw. In the PIBs, a mean detorque value of 20.20 Ncm was found. While comparable percentages in the range of 60% of the initial torque values were maintained in those screw types directly retaining the restorations, the abutment screws used in the conventional restorations showed detorque levels in the range of 80% of the tightening torque applied (Table 2). Consequently, no significant difference in detorque levels between occlusal screws and PIB retaining screws could be detected ($P = .5186$). The abutment screws showed significantly greater detorque values compared with occlusal screws ($P = .0002$) and PIB retaining screws ($P = .0000$) (Table 3).

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Part II: In Vivo

In vivo, detorque values ranging from 21.64 Ncm after 2 months to 27.81 Ncm after 6 months were recorded (Table 4). Thus the PIB retaining screws maintained between 61.80% and 79.37% of the 35 Ncm tightening torque applied (Table 5). An increase in detorque values over time was observed that was significant at all timepoints (Table 6).

Table 4 Mean (Standard Deviation) Detorque Values Measured In Vivo Following Fixation of the Procera Implant Bridges with 35 Ncm

Time after delivery of the restoration (mo)	Premolar (Ncm)	Molar (Ncm)	Total (Ncm)
2	21.81 (2.05)	21.48 (5.40)	21.64 (3.98)
4	24.59 (3.26)	26.48 (6.07)	25.54 (4.84)
6	27.43 (4.90)	28.19 (5.13)	27.81 (4.90)

Table 5 Mean (Standard Deviation) In Vivo Detorque Values Given as Percentage of the Tightening Torque Used for the Fixation of the Procera Implant Bridges

Time after delivery of the restoration (mo)	Premolar (%)	Molar (%)	Total (%)
2	62.28 (5.82)	61.33 (15.42)	61.80 (11.35)
4	70.19 (9.25)	75.54 (17.25)	72.86 (13.74)
6	78.27 (13.93)	80.46 (14.60)	79.37 (13.93)

Table 6 Pairwise Comparisons of In Vivo Detorque Values Measured After 2, 4, and 6 Months Following Delivery of the Restorations[1]

	4	6
2	.0009[2]	.0000[2]
4		.0038[2]

[1]One-sample *t* tests; *P* values adjusted for multiple testing by the Bonferroni-Holm method.
[2]Significant difference ($P < .05$).

Discussion

Detorque values have often been used to evaluate the stability of screw joints in implant dentistry.[15–18] In a clinical study comparable with the present study, a general decrease of approximately 30% of initial torque values was observed, independent of the implant system used.[16] Similarly, in an in vitro study on implant screw torque loss in single-unit restorations, Piermatti et al found values for torque loss ranging from 10% to almost 100% of the originally applied torque values depending on the implant system considered.[20]

Based on the in vitro study conducted, it can be stated that screws directly retaining a FDP lose about 40% of the tightening torque applied during the first months of service regardless of whether an additional abutment has been used. This seems to be in agreement with a previously performed finite element analysis showing that the loading situation of the screws mentioned was independent from the presence of an abutment.[10] However, with the abutment screws present in conventional restorations showing significantly less torque loss, it may be claimed that the use of an additional abutment bears a protective effect for the implant shoulder.

Repeated retightening of PIB retaining screws, as carried out in the in vivo study, reduced the level of torque loss over time. This seems to be consistent with Farina et al, who found a positive effect of retorquing retentive screws.[18] Despite the reduced levels of detorque relative to the tightening torque applied, none of the restorations were clinically mobile. It therefore cannot be inferred that a reduction in tightening torque means that the restoration becomes unstable, which is consistent with the existing literature.[20]

Since no uniform guidelines exist on how to perform meaningful in vitro studies involving masticatory simulation,[14,15,18] a clinical study was performed as a control.[1] Comparable levels of torque loss were recorded in vitro and in vivo.

Conclusion

This report suggests that the in vitro application of 100,000 load cycles had a comparable effect to in vivo detorque levels measured after 2 months.

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