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Narrow diameter titanium dental implants fracture resistance after implantoplasty

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SUMMARY

Background. There is a lack of evidence of possible implant fracture after implantoplasty due to decreased implant diameter.

Purpose. To compare narrow diameter titanium dental implants fracture resistance after implantoplasty performed by computer numerical control (CNC) lathe machine which helped to standardize study setting.

Materials and methods. Twelve (n=12) narrow diameter (3.6×11.0 mm) endosteal screw-shaped bone-level dental implants with an internal connection which are made from grade IV titanium were randomly divided into 2 groups containing six (n=6) implants each. The test group was exposed to implantoplasty using a computer numerical control (CNC) lathe-turning machine. Implantoplasty was performed removing 5.5 mm of implant threads from the implant coronal part downwards towards the apical part, which resulted in a 0.2 mm coronal diameter reduction. Implants from both groups were positioned on metal pipes using three-dimensional (3D) printed guides. The space inside the pipe was filled with epoxy resin. Every sample had an individually 3D-printed chrome-cobalt (Cr-Co) alloy crown, which distributed forces during the test. Implants were compressed in a universal testing machine. Statistical analysis was performed using IBM SPSS 29.0 software.

Results. Performing implantoplasty with CNC lathe-turning machine was a success, which helped to standardize study settings. The control group showed average resistance to a maximum compressive force of 443.76 N, while the test group showed average resistance to a maximum compressive force of 409.42 N. No statistical significance was found between groups on the compressive force aspect.

Conclusion. This *in vitro* study shows that implantoplasty does not have a significant effect on decreasing fracture resistance of narrow diameter titanium dental implants.

Keywords: Implantoplasty, implants, fracture, dental, CNC.

INTRODUCTION

Various studies show that dental implantation is an excellent treatment option for restoring edentulous spaces or replacing severely damaged teeth (1, 2). A positive effect of dental implantation is also reflected in the increased comfort of patients (3, 4). However, dental implants are often associated with systemic, prosthetic, and surgical complications (5). Sometimes it is impossible to pinpoint accurately why complications happen, this often leaves clinicians guessing about the exact complication reason (5, 6).

One of the most common complication associated with dental implants is peri-implantitis which Lee *et al.* reported to be 19.83% of the population (7). Peri-implantitis is described as progressive soft and hard tissue destruction around an implant (8). One of the peri-implantitis treatment methods is called implantoplasty (IP) (9, 10). The main goal of implantoplasty is to smoothen and polish the implant surface, which in return would stop further peri-implantitis progression (11-14). However, previous studies show conflicting results on implantoplasty procedure (15). Some authors found a close relationship between implantoplasty and its influence on the occurrence of implant fracture, especially in narrow-diameter dental implants (16-19). On the other hand, other studies did not find any significance (20-24).

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This *in vitro* study continues with the possible hypothesis of implantoplasty‘s effect on implant fracture. Previous research demonstrates that narrow diameter and the internal implant connection are one of the most important aspects for implant fracture to occur after IP (17-19). The current study uses bone-level, narrow-diameter, tapered, grade IV titanium dental implants with an internal connection. Implantoplasty was performed using automated computer numerical control (CNC) lathe machine. According to previous studies, some technical errors occurred because the different amount of material that the implant is made from was removed due to manual IP (17, 19-24). The amount of material that was removed was highly dependent on the operator‘s manual skills. Due to the manual IP technique, fracture resistance tests and statistical analysis were possibly negatively affected.

MATERIAL AND METHODS

In this *in vitro* study, twelve (n=12) narrow-diameter, bone-level, tapered, grade IV titanium, endosseous dental implants with internal conical connection were used (PrimeTaper EV Ø3.6 x 11 mm OsseoSpeed, Dentsply Implants Manufacturing GmbH, Sweden). All implants were randomly divided equally into two experimental groups. The control group (A) consisted of implants without implantoplasty, and the study group (B) consisted of implants with implantoplasty.

Implantoplasty was performed removing 50% of threads from the entire implant length from the neck towards the apical part. The same IP parameter was used in previously performed studies (17, 19, 20, 23). In this case, 5.5 mm of implant length was exposed to IP. Implantoplasty was performed on all the B group dental implants using a CNC lathe machine (V-turn II-20, Victor Taichung, China) with a reported error of ±0.002 mm. To avoid possible damage to an implant due to direct contact with the lathe machine’s dead center, temporary titanium abutments 9 mm in length (TempAbutment EV (S), Dentsply Implants Manufacturing GmbH, Germany) with temporary prosthetics screws (Abutment Screw EV, Dentsply Implants Manufacturing GmbH, Germany) were placed on an implant and tightened using a screwdriver (Hex Driver EV, Dentsply Implants Manufacturing GmbH, Germany) with hand force.

It was programmed to a CNC lathe machine to remove 3 mm from the most coronal implant part downwards towards the apex 0.1 mm of implant material in depth. The removal of remaining 2.5 mm of implant length was removed in tapering motion according to implant geometry removing 0.25 mm of material in depth (Figure 1).

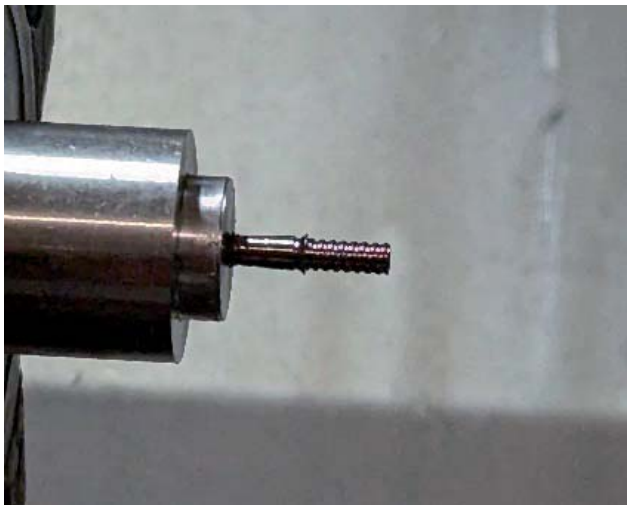

Fig. 1. An implant after implantoplasty

The implant diameter before IP was 3.6 mm and 3.4 mm after IP. Measurement was performed with a digital caliper (ABSOLUTE AOS, MITUTOYO, 500-181-30, Japan) (±0.02 mm). The measurement took place at the most coronal part of the implant, measuring 3 times at different areas. All the B group implants were polished with dynamic movements and the same pressure as possible for 30 seconds with a straight handpiece (NSK FX65, NSK, Japan) using a soft silicone polisher (Silicone polishers, Renfert GmbH, Germany) at 10 000 RPM. Polished implants were cleaned with a steam generator (STAR, REITEL GmbH, Germany).

A metal pipe of 20 mm in diameter was cut into 12 cylinder pieces 30 mm in length using a lathe machine. These cylinders served as a supporting structure for implant embedding into epoxy resin.

One metal cylinder and one B group implant were randomly selected for 3D scanning with a laboratory scanner (Freedom HD, DOF, South Korea) (±0.07 μm). To decrease light reflection from metal surfaces during scanning a scanning spray (Scanspray, Renfert GmbH, Germany) was used according to manufacturer‘s recommendations. STL files were imported into ‘‘exocad DentalCAD‘‘ (exocad GmbH, Germany) computer software. Using mentioned software a 3D virtual guide was made for even implant positioning onto the metal cylinder.

Using a 3D virtual design 12 positioning guides were printed from the resin (DENTAL MODEL PRO BEIGE, Liqcreate, Netherlands) using a DLP (Asiga MAX UV, Asiga, Australia) printer. Printed guides were hardened under UV light (Asiga Flash, Asiga, Australia) for 30 minutes and then centrifuged in

Fig. 2. On the left implant with a 3D printed guide, on the right implant with a detached guide

Fig. 3. Compression testing with a visible implant deformation

two washing baths (Wash and Cure 2.0, ANYCUBIC, China) one after another for 10 minutes filled with isopropanol (Kontakt IPA Plus, TermoPasty, Poland). On all 12 metal cylinders 12 guides with dental implants were placed, to ensure that the guides won't move by accident. Use of super glue (Super Moment universal, Henkel, Germany) was required to secure the guide onto the metal cylinder.

For implant embedding epoxy resin (Hesse Lignal ES3006, Hesse GmbH & CO. KG, Germany) was used with hardener (Hesse Lignal ES36, Hesse GmbH & CO. KG, Germany). The resin was mixed according to the manufacturer's recommendation: epoxy resin to hardener ratio 100:30. To weigh the epoxy resin and hardener digital kitchen scales were used (Standart EK9151-F347, China). Every metal cylinder was filled to the supposed bone-implantoplasty level and left to cure for 7 days undisturbed. After this period has passed plastic guide holders were cut off and the guide was detached from the temporary titanium abutment (Figure 2).

Using a previously scanned implant-abutment STL file 3D hemisphere crown model was designed. 12 crowns 11 mm in length were printed from Cr-Co using DMLS (Direct Metal Laser Sintering) technology. The hemisphere crowns helped to distribute forces evenly during the testing phase.

Testing was performed in the universal testing machine (H10KT Tinius Olsen, USA) with an attached sensor of 10 kN (±0.001 N). Samples were positioned 30 degrees to the vertical axis of the testing machine based on ISO 14801:2016 standards (Figure 3). The sensor's descendence speed was set at 1mm/min. The result was recorded when one of the following occurred: 1) implant fracture or 2) implant's complex deformation >30 degrees [18].

The sample size was based on Coray R. *et al.* systemic review and meta-analysis, which reported that 6 implants are needed per group with identical parameters group to make significant assumptions (18, 25). Statistical analysis was performed using IBM SPSS 29.0 software. A statistically significant decrease in compressive strength between the two groups was analyzed using the non-parametric analysis model of the Mann-Whitney U test for comparing values between groups. This non-parametric test was chosen because the distribution did not satisfy the conditions of normality. For the statistical hypothesis, a significance level of 0.05 was chosen, and a p-value <0.05 was considered statistically significant.

Table 1. Diameter of implants before and after implantoplasty

Sample order no.	Specimen diameter (mm) before implantoplasty	Specimen diameter (mm) after implantoplasty
1	3.60	3.40
2	3.59	3.39
3	3.60	3.40
4	3.60	3.40
5	3.60	3.40
6	3.60	3.40
Average:	3.598	3.398

RESULTS

Table 1 shows the apical diameters of the implants before and after IP using a CNC machine. We can see that the final implant diameter after IP using the CNC lathe machine had an error of 0.002 mm.

After compressive implant testing, descriptive frequency analysis was performed, additionally, for statistical significance a non-parametric Mann-Whitney U test was applied (Table 2).

The highest force in the control (A) group was 509.0 N, and the lowest was 369.2 N. In the experimental group (B) the maximum force was 536.25 N, and the minimum force was 296.8 N. These forces indicate the moment when the fracture or deformation of the implant or its prosthetic component occurred. The control (A) group‘s mean force difference was greater by 34.34 N, and the median by 56.75 N compared to the test (B) group. However, based on the non-parametric Mann-Whitney U test for two independent samples no statistically significant difference was found (p=0.423), which is higher than the previously mentioned value of 0.05.

DISCUSSION

The use of dental implants is becoming a more frequent treatment option for restoring severely damaged teeth and edentulous spaces. However, clinically we often face the complication of peri-implantitis. Successful treatment of peri-implantitis has emotional, financial, and psychological benefits. That’s why one of the treatment alternatives is implantoplasty. We can find a research article from 2013 that mentions the possible risk of implant fracture after IP. However, it is hard to compare studies on this subject due to heterogeneity and lack of method standardization.

This *in vitro* study used a CNC lathe machine for IP to unify implant diameters, which would avoid human error. The implant diameter of 3.6 mm and an internal connection were chosen because previous studies concluded that narrow-diameter dental implants (3.00 – 3.75 mm) had an increased risk for fracture to occur due to IP (17-19). However, to apply the IP technique with the CNC lathe machine, knowledge of the precise geometry of dental implants is a must, especially the depth of threads. The study of K. Bertl *et al.* also used a CNC lathe machine with narrow-diameter dental implants to perform IP which resulted in the removal of 0.13 mm of implant material (18). Just in their study, the implant diameter was 3.3 mm with a length of 10 mm. It is also important to mention that implant geometry was different from this *in vitro* study. A similar method of IP was applied by Gehrke *et al.* (16). However, IP was performed in a manually controlled lathe machine. The average implant diameter after IP was 3.25 ±0.03 mm, which demonstrates a higher error than the IP performed with the CNC lathe machine. On the other hand, the CNC lathe machine IP method doesn‘t reflect real clinical scenario, but it helps to standardize the study setting.

This *in vitro* study also evaluated the maximum fracture resistance of dental implants. No noticeable tendencies were found. It is hard to compare maximum fracture force because no other study used 3.6 x 11 mm dental implants. The closest study to this *in vitro* study was done by K. Bertl *et al.* (18). These authors found statistically significant differences between control and test group dental implants. However, differences in results could be explained by different bone-simulating materials (epoxy resins), implant diameter and length, different prosthetic parts, design nuances, and crown-to-implant ratio. It can be difficult to evaluate compression test results, because of different homogeneity materials (implants were embedded into epoxy resin). If there‘s no obvious implant fracture and only deformation is visible it might be difficult to interpret results because there‘s a possibility that epoxy resin gave out first, which caused artificial implant bending. It is also important to mention, that implant prosthetic components were temporary parts even though they were made from titanium, this aspect might have influenced results.

Furthermore, IP length might have clinical significance. A big part of previous studies on this topic performed IP by removing 50% of threads from the whole implant length (17, 19, 20, 23). According to the classification of peri-implantitis, this length falls into a moderate peri-implantitis stage that

Table 2. Distribution of maximum and minimum compressive forces in the studied groups. Non-parametric test data.

Descriptive frequency analysis				
Force, N	**Average; standard deviation**	**Maximum force**	**Minimum force**	**Median [25- 75%]**
Control (A) group	443.76 (55.34)	509.0	369.2	456.75 [382,.0-490.62]
Study (B) group	409.42 (77.91)	536.25	296.8	400.00 [363.70-462.18]
Non-parametric Mann-Whitney U test				
Groups	**N**		**Force, N (average rank)**	
Control (A) group	6		7.33	
Study (B) group	6		5.67	

* Mann-Whitney U test – 13.00; p>0.05.

ranges between 25% and 50% of bone loss around an implant (26). The same strategy was used in this study. However, the results were different from the other studies that performed IP by exposing 50% of implant length (17, 19). This could have happened, because of the current study's crown-to-implant ratio, which was 3:1. This ratio could be explained by the IP length that was 5.5 mm, the height of the abutment 9 mm (1 mm margin height and 8 mm vertical height), and the hemisphere crown that was 11 mm in height from the margin of the abutment. Leitao-Almeida B. *et al.* compared the coronal part's influence on implant fracture to occur (24). According to study results, there was a statistical significance for a fracture to occur if the CIR was 2.5:1, but they didn't find any significance if the CIR was 3:1. Because of this, further studies should focus more on height ratios.

CONCLUSION

The use of CNC to perform implantoplasty is a very accurate method that helps to standardize the study setting. There was no statistically significant difference between the control and test group in the fracture resistance of narrow-diameter titanium dental implants after implantoplasty.

STATEMENT OF CONFLICT OF INTEREST

The authors state no conflict of interest.

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REFERENCES

1. Pjetursson BE, Heimisdottir K. Dental implants - are they better than natural teeth? Eur J Oral Sci. 2018;126 Suppl 1(S1):81–7.
2. Zitzmann NU, Krastl G, Hecker H, Walter C, Weiger R. Endodontics or implants? A review of decisive criteria and guidelines for single tooth restorations and full arch reconstructions. Int Endod J. 2009;42(9):757–74.
3. Sargolzaie N, Moeintaghavi A, Shojaie H. Comparing the quality of life of patients requesting dental implants before and after implant. Open Dent J. 2017; 11(1):485–91.
4. Nickenig H-J, Wichmann M, Terheyden H, Kreppel M. Oral health-related quality of life and implant therapy: A prospective multicenter study of preoperative, intermediate, and posttreatment assessment. J Craniomaxillofac Surg. 2016;44(6):753–7
5. Kate M, Palaskar S, Kapoor P. Implant failure: A dentist's nightmare. J Dent Implant. 2016;6(2):51.
6. Kang D-W, Kim S-H, Choi Y-H, Kim Y-K. Repeated failure of implants at the same site: a retrospective clinical study. Maxillofac Plast Reconstr Surg. 2019;41(1):27.
7. Lee C-T, Huang Y-W, Zhu L, Weltman R. Prevalences of peri-implantitis and peri-implant mucositis: systematic review and meta-analysis. J Dent. 2017;62:1–12.
8. Smeets R, Henningsen A, Jung O, Heiland M, Hammächer C, Stein JM. Definition, etiology, prevention and treatment of peri-implantitis--a review. Head Face Med. 2014;10(1):34
9. Esteves Lima RP, Abreu LG, Belém FV, Pereira GH de M, Brant RA, Costa FO. Is implantoplasty efficacious at treating Peri-implantitis? A systematic review and metaanalysis. J Oral Maxillofac Surg [Internet]. 2021;79(11):2270–9.
10. Beheshti Maal M, Verket A. Implantoplasty- provoking or reducing inflammation? - a systematic scoping review. Acta Odontol Scand [Internet]. 2022;80(2):105–16.
11. Lozada JL, James RA, Boskovic M, Cordova C, Emanuelli S. Surgical repair of peri-implant defects. J Oral Implantol [Internet]. 1990;16(1):42–6.
12. Ramel CF, Lüssi A, Özcan M, Jung RE, Hämmerle CHF, Thoma DS. Surface roughness of dental implants and treatment time using six different implantoplasty procedures. Clin Oral Implants Res [Internet]. 2016;27(7):776–81.
13. Romeo E, Lops D, Storelli S, Ghisolfi M. Clinical peri-implant sounding accuracy in the presence of chronic inflammation of peri-implant tissues. Clinical observation study. Minerva Stomatol. 2009;58(3):81–91.
14. Bianchini MA, Galarraga-Vinueza ME, Apaza-Bedoya K, De Souza JM, Magini R, Schwarz F.: Two to 6-year disease resolution and marginal bone stability rates of a modified resectiveimplantoplasty therapy in 32 peri-implantitis cases. Clin Implant Dent Relat Res 2019; 21: pp. 758-765.
15. Goh R, Tawse-Smith A, Atieh M, Duncan W, Ma S, Li KC. The effect of implantoplasty on dental implant fracture resistance: a systematic review. IIUM Journal of Orofacial and Health Sciences. 2022;3(1):124–35.
16. Gehrke SA, Aramburú Júnior JS, Dedavid BA, Shibli JA. Analysis of implant strength after implantoplasty in three implant-abutment connection designs: An in vitro study. Int J Oral Maxillofac Implants. 2016;31(3):e65-70.
17. Camps-Font O, González-Barnadas A, Mir-Mari J, Figueiredo R, Gay-Escoda C, ValmasedaCastellón E. Fracture resistance after implantoplasty in three implant-

abutment connection designs. Med Oral Patol Oral Cir Bucal. 2020;25(5):e691–9.
18. Bertl K, Isidor F, von Steyern PV, Stavropoulos A. Does implantoplasty affect the failure strength of narrow and regular diameter implants? A laboratory study. Clin Oral Investig. 2021;25(4):2203–11.
19. Chan H-L, Oh W-S, Ong HS, Fu J-H, Steigmann M, Sierraalta M, et al. Impact of implantoplasty on strength of the implant-abutment complex. Int J Oral Maxillofac Implants. 2013;28(6):1530–5.
20. Sivolella S, Brunello G, Michelon F, Concheri G, Graiff L, Meneghello R. Implantoplasty: Carbide burs vs diamond sonic tips. An in vitro study. Clin Oral Implants Res. 2021;32(3):324–36.
21. Jorio IC, Stawarczyk B, Attin T, Schmidlin PR, Sahrmann P. Reduced fracture load of dental implants after implantoplasty with different instrumentation sequences. An in vitro study. Clin Oral Implants Res. 2021;32(8):881–92.
22. Leitão-Almeida B, Camps-Font O, Correia A, Mir-Mari J, Figueiredo R, ValmasedaCastellón E. Effect of bone loss on the fracture resistance of narrow dental implants after implantoplasty. An in vitro study. Med Oral Patol Oral Cir Bucal. 2021;26(5):e611– 8.
23. Costa-Berenguer X, García-García M, Sánchez-Torres A, Sanz-Alonso M, Figueiredo R, Valmaseda-Castellón E. Effect of implantoplasty on fracture resistance and surface roughness of standard diameter dental implants. Clin Oral Implants Res. 2018;29(1):46–54.
24. Leitão-Almeida B, Camps-Font O, Correia A, Mir-Mari J, Figueiredo R, ValmasedaCastellón E. Effect of crown to implant ratio and implantoplasty on the fracture resistance of narrow dental implants with marginal bone loss: an in vitro study. BMC Oral Health. 2020;20(1):329.
25. Coray R, Zeltner M, Özcan M. Fracture strength of implant abutments after fatigue testing: A systematic review and a meta-analysis. J Mech Behav Biomed Mater. 2016;62:333– 46
26. Passi D, Singh M, Dutta SR, Sharma S, Atri M, Ahlawat J, et al. Newer proposed classification of periimplant defects: A critical update. J Oral Biol Craniofac Res. 2017;7(1):58– 61

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