Abstract of Thesis

Name (Zhai Zhihao)	
Title	Influence of abutment material and implant diameter on implant deformation, abutment removal torque loss and static loading strength in conical connection implant-abutment assemblies after simulated long-term oral use （長期の口腔内使用を想定した条件下において，コニカルコネクションを有するインプラント体の直径およびアバットメント材料の違いが連結部の変形，アバットメント除去トルクおよび静荷重強度に与える影響）

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BACKGROUND: Zirconia implant abutment has been a well-adopted treatment option for its favorable esthetics. However, mechanical complications after long-term oral use, such as implant body deformation, abutment screw loosening, and strength degradation, remain as the primary concern. Existing studies have predominantly focused on only one aspect of mechanical performance and regular-diameter implant systems. Therefore, this study aimed to comprehensively investigate the influence of abutment material on the mechanical degradation of implant-abutment assemblies of different diameters after a simulated long-term oral use.

EXPERIMENT 1

Purpose: To investigate the influence of abutment material on implant body deformation and conical contact surface morphological change in implant-abutment assemblies of regular and narrow diameters after a simulated long-term oral use.

Material and methods: Six groups (n = 5 each) of CAD/CAM made abutments of three materials (T: one-piece titanium, CARES Ti, Straumann; Z: one-piece zirconia, CARES ZrO_2, Straumann; C: zirconia with a titanium alloy base, CARES ZrO_2 with Variobase, Straumann) and two diameters were fixed on implants of corresponding diameters (Bone Level Tapered Roxolid 10 mm, Straumann; Regular diameter, R: 4.1 mm, Narrow diameter, N: 3.3 mm) and then subjected to a standardized artificial aging process consisted of thermal cycling (TTS-1, THOMAS KAGAKU, 5 ℃ ⇆ 55 ℃, 2 min × 12,000 cycles) and mechanical cyclic loading (ElectroPuls E3000, INSTRON) with parameters corresponding to anterior (75 N 1.67 Hz × 0.8 million cycles) and posterior (150 N 1.67 Hz × 0.8 million cycles) mastication circumstances simulating a long-term oral use. μCT (R_mCT2, RIGAKU) scans of implant bodies were performed both before and after aging. 3D images of implant bodies before and after aging were generated from the μCT scans and 3-dimensionally aligned to calculate the amount of deformation. An observation of morphological change on implant conical contact surfaces was performed after aging using a scanning electron microscope (SEM, JSM6510LV, JEOL). Data were analyzed with one-way ANOVA tests with post hoc Tukey (HSD) tests ($\alpha = 0.05$).

Results: All samples survived artificial aging. Implant deformation amounts were 0.5116 ± 0.0991 mm^3 (ZR), 0.5582 ± 0.1532 mm^3 (TR), 0.6993 ± 0.0896 mm^3 (CR), 0.4879 ± 0.0546 mm^3 (ZN), 0.8841 ± 0.3283 mm^3 (CN), and 1.0478 ± 0.1454 mm^3 (TN). No significant difference was confirmed among regular groups ($p = 0.095$). In narrow groups, group ZN showed significantly less deformation than groups TN and CN ($p < 0.0001$). In SEM observation, groups ZR and ZN showed widespread distinct surface damage while only minor damage was confirmed in the other groups.

Conclusion: One-piece zirconia abutments showed better resistance to implant deformation in narrow diameter

after a simulated long-term oral use than those with metal connections.

EXPERIMENT 2

Purpose: To investigate the influence of abutment material on abutment removal torque loss in implant-abutment assemblies of regular and narrow diameters after a simulated long-term oral use.

Material and methods: Abutment removal torque test was done three times before aging and one time after aging using a digital torque meter (TME2, TOHNICHI) with all experiment 1 samples. The initial tightening torque was 35 Ncm as recommended by the manufacturer. Average of the three torque values measured before aging was adopted as initial abutment removal torque. Initial and post-aging torque loss values were calculated and analyzed using one-way ANOVA tests with post hoc Tukey (HSD) tests ($\alpha=0.05$).

Results: Initial torque loss values were 3.22 ± 0.98 Ncm (TR), 3.22 ± 0.62 Ncm (CR), 5.85 ± 0.39 Ncm (ZR), 1.13 ± 0.23 Ncm (CN), 1.34 ± 0.32 Ncm (TN), and 5.29 ± 0.20 Ncm (ZN). Groups ZR ($p < 0.0001$) and ZN ($p < 0.0001$) showed significantly greater initial torque loss. Post-aging torque loss values were 15.34 ± 4.98 % (CR), 15.59 ± 4.71 % (TR), 36.20 ± 3.75 % (ZR), 11.11 ± 3.41 % (TN), 13.55 ± 3.19 % (CN) and 42.01 ± 2.18 % (ZN). Groups ZR ($p < 0.0001$) and ZN ($p < 0.0001$) showed significantly greater post-aging torque loss.

Conclusion: Regardless of implant diameter, one-piece zirconia abutments tend to induce larger abutment removal torque loss than those with metal connections both initially and after a simulated long-term oral use.

EXPERIMENT 3

Purpose: To investigate the influence of abutment material on static loading strength degradation in implant-abutment assemblies of regular and narrow diameters after a simulated long-term oral use.

Material and methods: Samples survived aging in experiment 1, and 30 identical brand-new samples (n = 5 each) were subjected to a static loading test (ElectroPuls E3000, INSTRON) till failure. Maximum load values were analyzed with two-way ANOVA tests with post hoc Tukey (HSD) tests ($\alpha=0.05$).

Results: In regular groups, maximum load values were 556.49 ± 11.57 N (ZR), 840.68 ± 29.34 N (CR), 849.34 ± 42.51 N (TR) for brand-new samples and 530.51 ± 53.81 N (ZR), 774.99 ± 28.03 N (TR), 802.83 ± 48.02 N (CR) for aged samples. In the narrow groups, maximum load values were 311.17 ± 22.18 N (ZN), 421.63 ± 6.36 N (CN), 440.48 ± 14.13 N (TN) for brand-new samples, and 317.28 ± 22.21 N (ZN), 425.39 ± 14.56 N (TN), 434.27 ± 12.19 N (CN) for aged samples. Significant static loading strength degradation after aging was not confirmed for all tested abutment materials and implant diameters ($p > 0.05$). One-piece zirconia groups showed significantly lower strength than the other two materials ($p < 0.0001$).

Conclusion: Regardless of implant diameter, one-piece zirconia abutments showed lower static loading strength than those with metal connections before and after a simulated long-term oral use. The degradation of static loading strength in implant-abutment assemblies of the tested materials and diameters after a simulated long-term oral use was limited.

GENERAL CONCLUSION

Concerns about one-piece zirconia abutment inducing larger implant deformation and static loading strength degradation after long-term oral use may be unnecessary. On the other hand, adopting such abutments may lead to more abutment removal torque loss and lower strength.

様式 7

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本研究は，コニカルコネクションを有する 2 種類の直径のインプラント体に，3 種類の材質のアバットメントを連結し，長期的な口腔内使用を想定したサーマルサイクルおよび繰り返し荷重試験を行い，変形，アバットメントスクリューの除去トルク，および静荷重試験による多面的な評価を行ったものである．

その結果，ワンピースタイプのジルコニアアバットメントは，チタンアバットメントやチタンベースを用いたジルコニアアバットメントに比べて，強度やアバットメントスクリューのトルク維持が劣ること，一方，インプラント体直径が小さい場合は，インプラント体の変形防止に優れることが示唆された．

以上の研究成果は，ジルコニアアバットメントの使用基準に臨床上の有益な新しい知見を提供するものであると考えられ，博士（歯学）の学位論文として価値のあるものと認める．