Original Article

The Influence of Implant Surface Characteristics on Stress Distribution in Areas of Poor Quality Bone Under Lateral Loading: An in Vitro Study of Machine-Thread and Sintered Porous Surface Texture

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Abstract

The purpose of this study was to examine the influence of implant surface characteristics on stress distribution in areas of poor quality bone under lateral loading. Comparisons were performed with porous surface implants and machined-surface implants with strain gauges on the in vitro bone analog. The results suggest that porous surface implants have the advantage of distributing stress to bone around the implant more evenly than machined-surface implants, especially in the case of poor quality bone.

Key words: implant, surface characteristics, stress distribution, in vitro study

Introduction

The advantages of a rough surface over a machined surface include increases in the surface area, the initial bone-implant contact, the rate of bone formation, and the initial stability for immediate loading.[1] Deporter et al[2] suggested that rough surfaces have a better prognosis than machined surfaces with functional loading; however, few studies have examined the biomechanical influences involved.

Unlike other features of implants such as diameter and length, it is not possible to simulate the microstructure of rough surfaces using three-dimensional finite element models. In vitro models that simulate bone analogs should therefore be considered when examining the biomechanical significance of such implants under unfavorable loading configurations. The purpose of this study was to examine the influence of implant surface characteristics on stress distribution in areas of poor quality bone under lateral loading.

Materials and methods

Two types of (12 × 4mm) implants, one with a porous surface without thread (Group I)(Endopore; Innova, Toronto, Canada) and the other with a machined surface with thread (Group II) (GC; Tokyo, Japan), were embedded in a (20 × 20 × 17mm) block constructed with auto-polymerizing resin material to simulate poor quality bone.[3] Healing

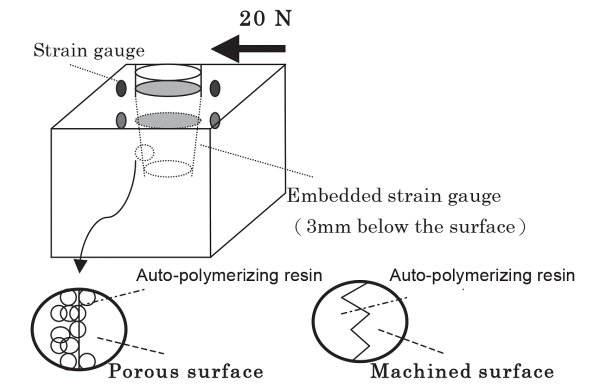

Fig. 1: Illustration of the measurement model and test conditions. Left: porous-surface implant Right: machined-surface implant. Major stress concentration around the neck area was measured using strain gauges placed 3mm away from the edge of the implant. A lateral force of 20N (arrow) was applied to the tip of the abutment.

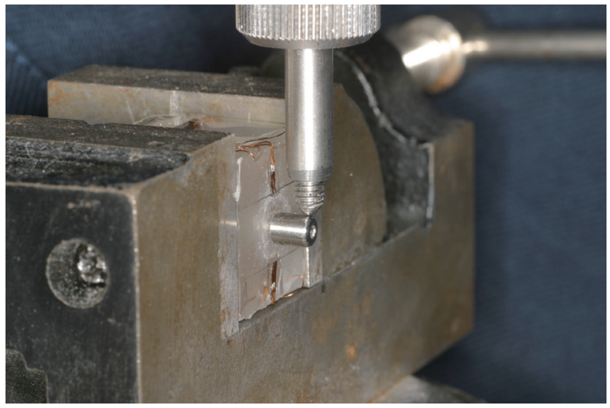

Fig. 2: A model mounted on a lever-type testing machine. Non-impact lateral force of 20N was applied perpendicular to the superstructure, and static strain was recorded for 30 seconds.

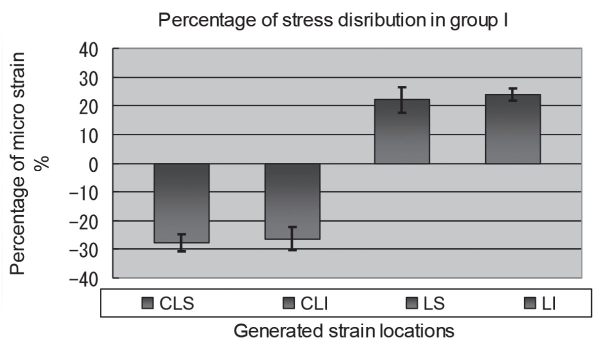

Fig. 3: Stress distribution in Group I.

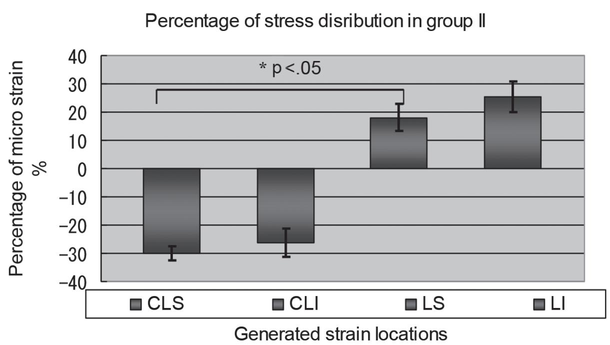

Fig. 4: Stress distribution in Group II.

abutments of 5 mm in height were connected to the implants (Table 1). Strain gauges (Type KFG-1N-120-C1-11, Kyowa, Japan) were then attached on the bone surface 3mm away from the edge of the fixture platform and embedded in the block 3mm below the surface and 3mm away from the edge of the implant on both the loading side and the contralateral side (total: n=4). Three samples were prepared for each implant type. Outputs from the strain gauges were transferred to an A/D converter through an amplifier (PCA-300, Kyowa) with purpose-built software (PCD-30A, Kyowa) (Fig. 1). Strain gauge outputs of each model were calibrated with known loads, and linearity with an error of less than 5 % was confirmed. The occlusal load consisted of an axial and a horizontal load. To simplify the clinical condition, a static horizontal load of 20N was then applied to the tip of the abutment simulating the occlusal force (Fig. 2). Strain data obtained on the surface of the loading (LS) and the contralateral side (CLS) and on the inside of the loading (LI) and contra lateral side (CLI) for each model were normalized as a percentage of the sum of the above following our previous report.[4] Results of both groups were analyzed with one-way analysis of variance (ANOVA) ($p<0.05$), and those of the 4 different areas within each group were compared using a 2-tailed t test ($p<0.05$).

Results

In both groups, tensile strain was observed on the loading side and compressive strain was observed on the contralateral side. In Group I, there were no significant differences between the loading side and the contra-lateral side (LS vs. CLS, LSI vs. CLI) or between the surface and inside of the bone (LS vs. LI, CLS vs. CLI) (Fig. 3). In Group II, there was a significant difference between the surface strains on the

Table 1 Characteristics of the implants and abutment

	Characteristics	Product name	Dimensions	Number examined
Group I	Porous surface without thread	Endopore implant Innova, Toronto, Canada	Diameter: 4mm Length: 12mm	3
Group II	Machined-surface with Thread	GC implant system Tokyo, Japan	Diameter: 4.1mm Length: 12mm	3
Abutment		Endopore implant Innova, Toronto, Canada	Height: 5.0mm	Used in all tests

loading side and on the contra lateral side (LS vs. CLS; $p<0.05$). Most of the strain was concentrated at the level of the fixture platform on the compression side (CLS). There were no significant differences between the surface and inside of the bone (LS vs. LI, CLS vs. CLI) in Group II (Fig. 4).

Discussion

Hansson and Norton[5] indicated that rough-textured threaded implants have larger resistance to shearing force during functional loading than machined-surface implants. Moreover, the resistance of osseointegration to tensile stress might be more critical with soft or poor quality bone when a dense cortical layer of bone is missing, as shown in this study with auto-polymerizing resin material.

Our results indicate that porous surface implants have the advantage of distributing stress more evenly, minimizing the risk of bone resorption and exfoliation both on the compression side and tension side. However, the geometries of rough surface thread implants might not always significantly improve the ability of implants to resist tensile forces caused by transverse force components. The effects of surface roughness and pore size should therefore be further examined in relation to bone formation as well as resorption. In the present study, the macro-architecture of a porous surface without thread and a machine surface with thread were evaluated. However, there are still other important factors, such as rough surface with thread, different thread designs, which might also influence the results. These factors should be evaluated in the further studies.

Conclusions

Within the limitations of this in vitro study, porous surface implants were shown to have the advantage of distributing stress to bone around the implant more evenly than machined-surface implants, especially in the case of poor quality bone.

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Literature Review

Endodontically Treated Teeth : Considerations to Restore Them

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Abstract

The restoration of endodontically treated teeth is a topic that is extensively studied and yet remains controversial. This article discusses the characteristics of endodontically treated teeth and some principles to be observed when restorations of these teeth are planned. The best current approach for restoring endodontically treated teeth seems to minimize structure sacrifice, especially in the cervical area, use post with physical properties close to the dentin and use adhesive procedures.

Keywords: **Endodoontically treated teeth, restoration, dentin, tooth structure, irrigant**

Introduction

What is endodontology, or what, in other words, is encompassed by the practice of endodontics? The definition may be modified from the definition provided by the American Association of Endodontists. Endodontics is that branch of dentistry that is concerned with the morphology, physiology and pathology of the human dental pulp and periradicular tissue. For more than 200 years, various methods for restoring pulpless teeth after root canal therapy have been reported. Gillen et al[1] used a meta-analysis method to determine the impact of the quality of coronal restoration and root canal fillings on the success of root canal treatment. The result from 9 selected studies indicated that the odds of healing in cases of apical periodontitis increase with both adequate root canal treatment and adequate restorative treatment. The finding that adequate restoration and root canal treatment produce better treatment outcomes reinforced the fundamental biologic principle of preventing bacteria ingress via the concerted efforts of endodontists and restorative dentists, indicating that such combined efforts provide the highest quality of care in saving functional teeth.

Should Crowns and Posts Be Placed on Endodontically Treated Teeth?

One study compared the clinical success of 1273 teeth treated endodontically in the preceding 1 to 25 years[2]. It was determined that coronal coverage crowns did not significantly improve the outcomes for endodontically treated anterior teeth. This finding supports the use of a conservative restoration such as an etched resin restoration in the access opening of otherwise intact or minimally restored anterior teeth. Crowns are indicated only on the teeth when they are structurally weakened or require significant form or color changes. Scurria et al collected data from 654 general dentists regarding endodontically treated teeth[3]. The results indicated that 67% of endodontically treated anterior teeth were restored with- out a crown. These data support the concept that anterior teeth are being satisfactorily restored without crowns.

When endodontically treated posterior teeth were compared, a significant increase in clinical success was noted when cuspal coverage crowns were placed on molars and premolars[2]. Placing a crown on an endodontically treated posterior tooth enhances survival[4]. In contrast, Nagasiri's study indicated that when endodontically treated molars are completely intact except for a conservative access opening, they can be restored successfully by using composite resin restorations[5]. In addition, Mannocci et al evaluated the success rate of endodontically treated premolars with and without crown coverage, and found that both approaches had a similar success rate[6].

Endodontically treated dog teeth have been found to have 9% less moisture than vital teeth[7]. This dehydration increases stiffness and decreases the flexibility in teeth. However, dehydration does not account for the physical property changes in dentin[8]. Endodontic procedures reduce tooth stiffness by 5%, and this reduction is attributed primarily to the access opening[9]. Restorations that encompass the cusps of endodontically treated posterior teeth have been found to increase the longevity of these teeth. Therefore, crowns should be placed on endodontically treated posterior teeth that have occlusal intercuspation with opposing teeth that places expansive forces on the cusps[10].

Laboratory and clinical data have failed to support the concept that posts strengthen endodontically treated teeth. Therefore, the purpose of a post is to provide retention for a core. A wide range or recommendations have been made regarding post length. To minimize stress in the dentin and in the post, the post should extend more than 4 mm apical to the bone. Therefore, the key question is how much gutta-percha should be retained to preserve the apical seal. There is greater leakage when only 2 to 3 mm of gutta-percha is present. Four to 5 mm should be retained apically to ensure an adequate seal[11-14]. Solano et al found a less significant difference in apical leakage between teeth whose post spaces were prepared at the time of the obturation and 1 week later using warm gutta-percha condensation and AH plus sealer[15]. However, several studies have indicated that there is no difference in the leakage of the root canal filling material when the gutta-percha is removed immediately after root canal treatment[16,17]. Rubber dam isolation is necessary for post space preparation. Using a rubber dam can prevent bacterial contamination, and such contamination is the key factor in the outcomes of root canal treatments.

Following root canal therapy, post space preparation should be performed and a post definitively cemented as soon as possible. Both rotary instruments and hot hand instruments can be safely used to remove adequately condensed gutta-percha when 5 mm is retained apically. The prepared tooth should then be restored with a provisional restoration with good marginal seal and occlusion. The definitive crown can be cemented in as short a time as possible.

Reports regarding the mechanical properties of zirconia posts have stated that these posts are very stiff and strong with no plastic behavior[18,19]. Kaya and Ergun evaluated the effect of different core materials and post length on the fracture strength of different posts[20]. The fracture patterns observed in teeth restored with fiber posts were more favorable than those for teeth restored with zirconia posts. A higher restoring success rate can be achieved by fiber posts rather than zirconia posts, since the failure mode for these posts would be restorable. From the viewpoint of endodontics, retreatment is made more difficult by a zirconia post, to the extent that the use of a zirconia post might change the treatment plan. For example, if the removal of a zirconia post will sacrifice more dentin structure, apical surgery will be the choice instead of retreatment.

The loss of marginal ridges and pulp chamber roof, the enlargement of root canal orifices, coronal flaring and preparation of the root canal, the use of disinfectants and intracanal medicaments, the selection of the sealer and obturation technique, and finally the type and quality of coronal restoration (including occlusal adjustment) implemented form a chain of treatment steps with a cumulative effect on the remaining root and tooth tissues and their chemical and physical properties. The main aspects of the effect of the most frequently used irrigants on radicular dentin and surrounding tissues will be presented and discussed.

The Effect of Irrigants

Chemical treatments have been reported to affect both the physical and bonding properties of dentin, and are more closely related to clinical procedures involving coronal and root dentin.

Sodium hypochlorite (NaOCl) is a well-known, non- specific proteolytic agent that is capable of removing organic material and bacteria from the canal space. Dentin is composed of approximately 20% organic material, so it is not surprising that exposure to sodium hypochlorite influences the physical properties and chemical structure of this substrate. Several studies have demonstrated that NaOCl compromises the bond strength between adhesive agents and dentin[21-23]. Exposure of dentin to sodium hypochlorite affects the organic components of dentin and alters its chemical and mechanical properties (flexural strength and elasticity). These effects are time-dependent and concentration-dependent[24-27].

Chlorhexidine shows good antibacterial efficacy against a broad spectrum of microorganisms, making it a good solution for endodontic irrigation. Unfortunately, it does not dissolve tissues, either organic or inorganic. It does not affect the collagen present in the organic dentin matrix[28]. Chlorhexidine has an inhibitory effect on MMPs (matrix metalloproteinases), thereby suppressing collagenolytic processes and preventing degradation of the bond[27]. The use of chlorhexidine during the bonding procedure to increase the longevity of dentin bond strength is recommended for clinical practice. This is good for post cementation.

Calcium hydroxide has been widely used in endodontics as an intra-canal medicament between appointments. In an aqueous solution, calcium hydroxide dissociates into calcium and hydroxyl ions. Various biological properties have been attributed to this substance, such as antimicrobial activity[29], tissue-dissolving ability[30], inhibition of tooth resorption[31], and induction of repair by hard tissue formation[32]. In an in vitro study conducted by Andreasen et al., immature mandibular sheep incisors were medicated with calcium hydroxide ($Ca(OH)_2$) for 0.5, 1, 2, 3, 6, 9, or 12 months[33]. Within 1 year, the fracture resistance decreased to one-half of the initial value. After only 2 months, a clear reduction from 16.9 MPa to 12.1MPa was observed. These results were confirmed in Andreasen's other study[34]. The results showed a decrease in the fracture resistance of the incisors with $Ca(OH)_2$ in the root canals after 100 days of storage, compared to teeth stored in intracanal saline, and teeth with $Ca(OH)_2$ placed in the canals for 30 days and then filled with MTA. These results supported the conclusion that $Ca(OH)_2$ significantly reduces dentin microhardness and strength. Accordingly, prolonged exposure should be avoided.

As outlined above, the use of irrigants and intracanal medicaments will alter the properties of root dentin. One sequela of these alterations is reduced bond strength between root dentin and obturation materials. This is important when new materials applied with dentin adhesives are used for obturation or restoration of endodontically treated teeth, or during the adhesive insertion of root posts. The influence of the sequence of use of medicaments and irrigants on the adhesion to dentin has thus far not been sufficiently investigated. Clinical evidence on this topic is still lacking.

In the future, strategies and techniques should be developed toward reducing or neutralizing these unwanted negative effects and maintaining or improving the strength of endodontically treated teeth.

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