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Finite element analysis of bone loss around failing implants

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ABSTRACT

Dental implants induce diverse forces on their surrounding bone. However, when excessive unphysiological forces are applied, resorption of the neighbouring bone may occur. The aim of this study was to assess possible causes of bone loss around failing dental implants using finite element analysis. A further aim was to assess the implications of progressive bone loss on the strains induced by dental implants. Between 2003 and 2009 a total of 3700 implant operations were performed in a private clinic. Ten patients with 16 fixtures developed severe marginal bone defects. Finite element analysis was used to assess the effective strains produced at the bone-implant interface under unidirectional axial loading. These simulations were carried out on 4 specific implant types – Camlog Plus, Astra Osseo Speed, Straumann BL and Straumann S/SP. All implant types exhibited degraded performance under circular and horizontal bone loss conditions. This is evidenced by increased distribution of pathological strain intensities (>3000 $\mu\varepsilon$), in accordance with the mechanostat hypothesis, in the surrounding bone. Among the implants, the Camlog design seemed to have performed poorly, especially at the chamfer in the implant collar (>25000 $\mu\varepsilon$). Implants are designed to perform under nearly ideal conditions from insertion till osseointegration. However, when the surrounding bone undergoes remodelling, implant geometries can have varied performance, which in some cases can exacerbate bone loss. The results of this study indicate the importance of evaluating implant geometries under clinically observed conditions of progressive bone loss.

1. Introduction

When dental implants are placed into bone it is expected that they will remain functional for a lifetime; however complications do occur. According to Esposito et al., implant failures can be categorised chronologically into ‘early failures’ and ‘late failures’ [1]. It is suggested that early failures occur before abutment connection and occlusal loading. Such failures are often caused by interferences in the initial healing process leading to non-integration of the implant. Late failures have been described as occurring after occlusal loading [2]. According to Koldsland et al., most failures tend to occur at an early stage, that is, before occlusal loading [3]. One common cause of interference in the initial healing process is surgical trauma. The drilling forces induced intraoperatively are very subjective and are influenced by the perceptual and motor skills of the clinician involved. When excess forces are applied during drilling, mechanical and thermal damage can occur to the surrounding bony tissue and thereby jeopardize the establishment of osseointegration [4].

Adaptive changes that take place when bone loading occurs can influence the initial healing process, a phenomena first described by Wolff in 1892 [5]. In the 1960s, Frost introduced the mechanostat hypothesis that is a refinement of Wolff’s law [6]. The hypothesis attributes strain values between 1000 $\mu\varepsilon$ and 1500 $\mu\varepsilon$ to be physiological, which can be attained during normal mastication.

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Table 1
Details of failed/failing implants observed in the clinical case pool.

Case no.	Sex	Age	Time (months)	Loss type	Region	Implant type	Dimensions (mm)
1	F	33	2	Circular	46	Camlog Plus	5 × 11
2	M	64	1	Circular	36	Camlog Plus	5 × 11
3	F	42	3	Circular	36	Camlog Plus	3.8 × 9
4	F	46	2	Circular	36	Camlog Plus	3.8 × 11
					37	Camlog Plus	3.8 × 9
5	F	60	1	Circular	47	Camlog Plus	4.3 × 11
6	M	53	9	Horizontal	13	Camlog Plus	4.3 × 11
					14		4.3 × 11
					15		4.3 × 9
					22		3.8 × 11
					24		3.8 × 11
					26		4.3 × 9
7	F	68	5	Circular	14	Straumann BL	4.1 × 10
8	F	55	3	Circular	47	Astra Osseo Speed	4 × 11
9	F	83	12	Circular	47	Straumann S	4.1 × 12
10	F	56	4	Circular	36	Straumann SP	4.1 × 10

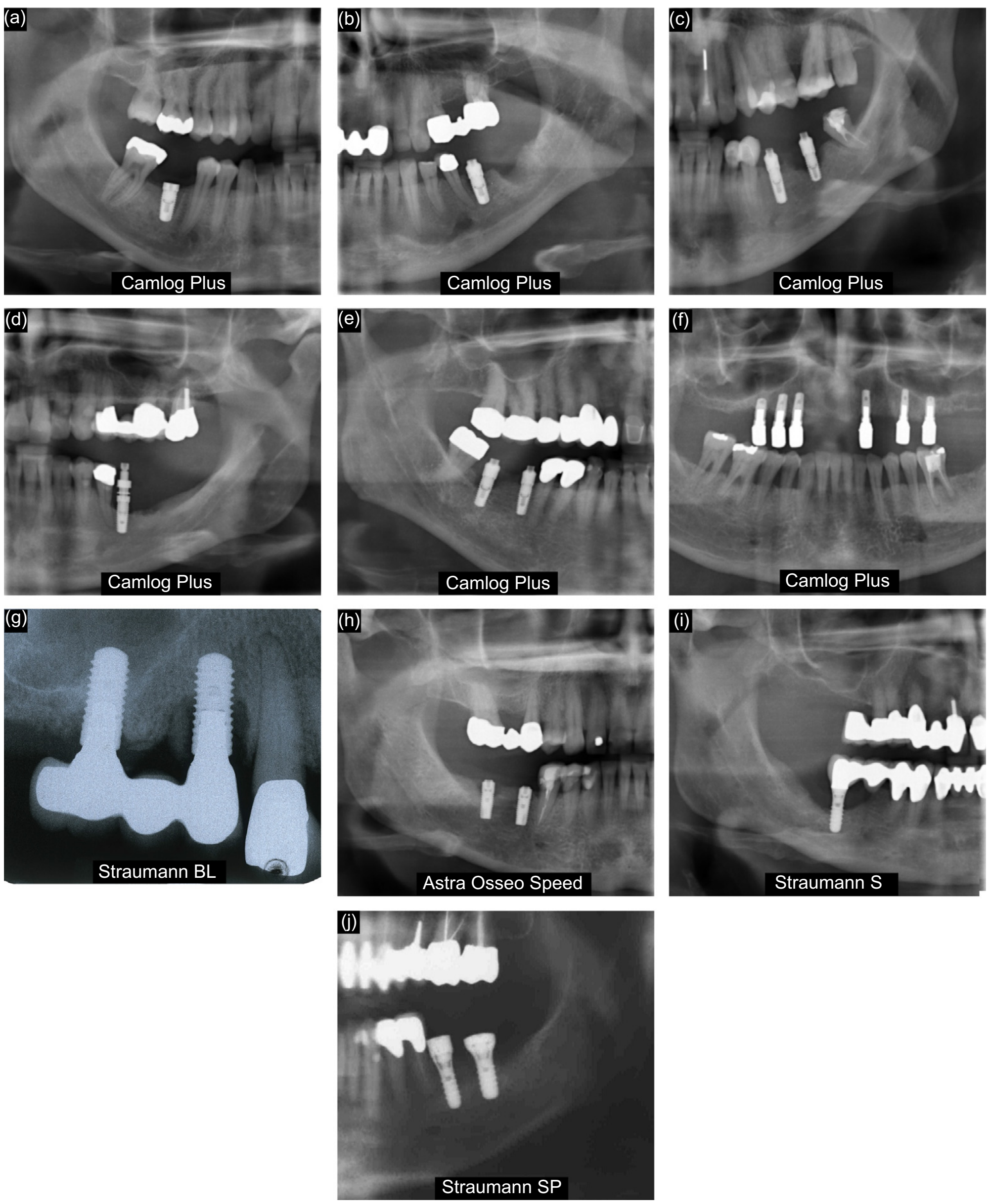

Fig. 1. Radiographs demonstrating circular and horizontal bony defects observed around implants.