

四种桩材料对牙本质应力分布影响的三维有限元分析

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摘要 选用计算机建立上颌中切牙金属烤瓷核桩冠三维有限元模型,分别分析 SDA-II 型中熔合金桩、复合树脂桩、Ni-Cr 高熔合金内层加复合树脂外层复合桩及 SDA-II 型中熔合金内层加复合树脂外层复合桩修复后的牙本质应力分布状况。结果表明:金属桩降低牙本质应力峰值作用较明显,但改变牙本质内原有的应力分布模式,在桩与牙本质交界处出现应力集中现象;复合树脂桩不改变牙本质内原有应力分布模式,但降低应力峰值作用不明显;而复合桩一方面避免了桩与牙本质交界处出现应力集中,另一方面具有较单纯的复合树脂桩更好的强度。从力学角度分析提示:金属内层增强的复合桩可能是一种较理想的桩设计。

关键词 桩材料 桩核修复 牙应力分析 三维有限元法 牙本质 金属烤瓷冠

桩材料选择是修复设计的一个重要部分。常用作桩的材料有:金合金、不锈钢、钛合金、铜锌合金、汞合金以及复合树脂等。以往的观点认为¹应选择弹性模量较高的桩材料,这样在去除少量牙体组织,桩的直径较小时也能达到强度要求。但 1980 年 Ross² 临床研究表明:牙根垂直折裂与桩修复相关;1992 年 Bex 等³ 提出使用与牙本质具有类似弹性模量的复合树脂桩,树脂桩在受到较大的冲击载荷时,先于牙体发生折裂,缓冲载荷进而保护了牙体组织;相反,金属桩由于弹性模量与牙本质相差较远,当受到过大的冲击载荷时,首先发生折裂的是强度低的牙体组织。另有学者报道⁴ 非贵金属材料的桩可出现表面腐蚀现象,并可能成为垂直根折的诱因。尽管如此,由于贵金属价格昂贵,化学性能相对稳定的非贵金属仍广泛应用于临床。鉴于上述原因,作者选择国内常用的 SDA-II 型中熔合金、Ni-Cr 高熔合金及复合树脂作为本实验的基本材料组成,分析桩材料对牙本质应力分布的影响,以供临床参考。

1 材料和方法

1.1 三维有限元模型的建立

三维有限元模型的建立及模拟咬合力加载见参考文献 5。

1.2 桩材料的选择

SDA-II 型中熔合金桩、复合树脂桩、SDA-II 型中熔合金增强的复合树脂桩(内层 1/2 为 SDA-II 型中熔合金,外

层为复合树脂,下文简称复合桩 1)、Ni-Cr 高熔合金增强的复合树脂桩(内层 1/2 为 Ni-Cr 高熔合金,外层为复合树脂,下文简称复合桩 2)。

2 结果

2.1 牙本质内 Von mises 应力、最大主应力、最小主应力峰值

4 种不同材料桩修复时,牙本质内 Von mises 应力、最大主应力、最小主应力峰值结果见表 1。

结果显示:相同桩径桩长条件下,桩的弹性模量高,相应的牙本质应力峰值较低,即弹性模量高的桩对于降低牙本质应力峰值作用更为明显;而采用金属支架增强的树脂桩(复合桩)修复,降低牙本质应力峰值作用介于金属桩和单纯树脂桩之间。

2.2 牙本质内 Von mises 应力分布

上颌中切牙唇舌方向牙本质内 Von mises 应力分布见图 1~4。4 种不同材料桩修复时结果显示:弹性模量高的金属桩,牙本质内 Von mises 应力高应力区由唇舌侧颈部牙根表面延伸至桩与牙本质交界处;而弹性模量低的复合树脂桩及复合桩(树脂部分与牙本质直接相邻),其牙本质 Von mises 应力高应力区均位于唇舌侧颈部牙根的外部牙本质内。

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表1 4种材料的桩修复牙本质应力峰值(单位:MPa)

修复方式	Von mises 应力(降低率 %)		最大主应力(降低率 %)		最小主应力(降低率 %)	
桩修复前	27.9		29.8		- 35.2	
SDA-II型中熔合金桩	24	(13.98)	27.7	(7.05)	- 31.1	(11.65)
复合树脂桩	27.2	(2.51)	29.5	(1.01)	- 35.1	(0.28)
复合桩1	26.9	(3.58)	29.5	(1.01)	- 34.7	(1.42)
复合桩2	26.6	(4.66)	29.5	(1.01)	- 34.4	(2.27)

注:降低率为上述4种材料桩修复后与修复前牙本质应力峰值相比的降低率

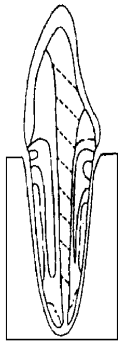


图1 SDA-II型中熔合金桩修复牙本质内Von mises 应力分布

10.0~50.0MPa, - - - 5.0~10.0MPa,
 - · - · 1.0~5.0MPa, 0.1~1.0MPa,
 · · · < 0MPa, 下同

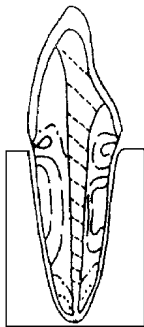


图2 复合树脂桩修复牙本质内Von mises 应力分布

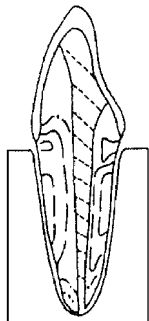


图3 复合桩1修复牙本质内Von mises 应力分布

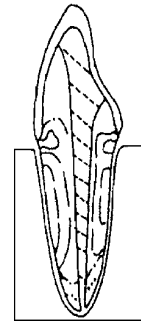


图4 复合桩2修复牙本质内Von mises 应力分布

2.3 牙本质内最大主应力分布

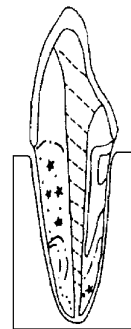


图5 SDA-II型中熔合金桩修复牙本质内最大主应力分布

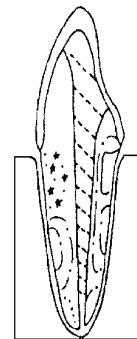


图6 复合树脂桩修复牙本质内最大主应力分布

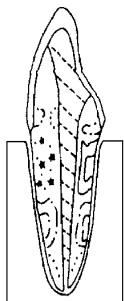


图7 复合桩1修复牙本质内最大主应力分布

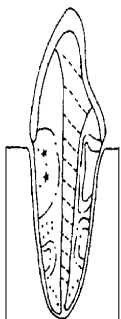


图8 复合桩2修复牙本质内最大主应力分布

4种材料桩修复后, 上颌中切牙唇舌方向牙本质内最大主应力分布见图5~8。结果显示: SDA-II型合金桩修复, 其牙本质内最大主应力高应力区由无桩修复时的舌侧颈部牙本质延伸至舌侧桩与牙本质交界处; 而复合树脂桩及复合桩修复后的牙本质最大主应力高应力区均位于唇舌侧颈部牙根外部本质内。

3 讨 论

1994年, Assif等⁶从生物力学角度阐明: 由于桩所处的位置为牙根受力的中性区, 故桩实际所承受和传递的应力都较小, 因此作者认为桩更主要是作为一种固位设计。本实验比较4种不同材料的桩修复后, 牙本质应力分布规律, 结果与上述结论存在一定的差异, 本实验结果表明, 桩修复后其应力分布规律与桩材料的弹性模量密切相关: 与桩修复前相比⁵, 采用高弹性模量的SDA-II型中熔合金桩, 牙本质内Von Mises应力、最大主应力高应力区均由牙颈部沿桩与本质交界处向根尖方向扩展, 因此, 作者推测: 弹性模量较高的金属桩修复既然可以在桩与牙本质交界处形成应力集中, 就有可能改变牙根原有的受力分布规律, 使桩所处的位置由牙根受力的中性区变为非中性区, 从而发挥传递分散力作用。与金属桩比较, 弹性模量与牙本

质相近的复合树脂桩修复后牙本质应力分布规律与桩修复前相似⁵, 仅仅表现为修复后高应力区范围缩窄, 整体应力分布较均衡, 但高应力区仍位于牙根颈部外侧, 即复合树脂桩所处位置为牙根受力的中性区, 故单纯复合树脂桩修复后, 仍有可能出现颈部折断现象。

综合上述分析, 由于SDA-II型中熔合金的弹性模量是复合树脂弹性模量的10~12倍, 是牙本质弹性模量的5倍, 故具有改变应力分布的能力, 可在桩与牙本质交界区形成高应力区, 扩大了高应力区的范围, 改变了天然牙原有的应力分布模式, 但与此同时, 降低牙本质峰应力。而复合树脂桩由于材料弹性模量低, 故改变应力分布作用不明显, 只是缩窄颈部高应力区范围, 同时强度过低始终是复合树脂的主要缺点⁷, 所以尽管有学者²提出采用复合树脂桩, 却未被广泛采用。由于本实验显示: 高弹性模量的桩将应力集中在桩周的牙本质界面上, 而弹性模量低的复合树脂桩不会出现类似现象, 即从力学角度提示, 可在复合树脂中置入高弹性模量的金属增强支架, 形成复合桩。复合桩一方面不会在桩周界面形成应力集中, 而是将应力集中在复合桩的金属内层与复合树脂外层之间⁸; 另一方面具有较好强度, 从而在一定程度上保护了牙体组织。

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Analysis of 4 Different Post Materials on Dental Stress of Maxillary Central Incisor Restored with PFM Crown with Three-dimensional Finite Element Method

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Abstract

In order to know how post materials influenced dental stress distribution, the models of maxillary central incisor restored with porcelain fused to metal crown and post of 4 different materials were constructed by using the three-dimensional approach with finite element method, and whose 4 different posts were SDA-II alloy post, composite resin post, the inner Ni-Cr alloy with the outer resin post and the inner SDA-II alloy with the outer composite resin post. The results showed that metal post with high elastic modulus reduced the peak of dental stress to some extent but changed the pattern of the stress distribution with high stress concentrating at the border between the post and the dentin. The resin post with low elastic modulus would not alter the original inclination of the dental stress distribution, but had little influence on lessening the dental peak stress. Furthermore the compound resin post strengthened with metal alloy restoration did not cause stress focusing on the dentin around the post, on the other hand, the inner alloy structure enhanced the post itself. The results suggest mechanically that the inner alloy with the outer composite resin post is possibly a good post design.

Key words: post material post and core technique dental stress analysis three-dimensional finite element method dentin porcelain fused to metal crown

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tory efficiency of the patients wearing the immediate complete dentures for 3 months were measured by using the light absorption method. The results showed: The alveolar horizontal absorption was obvious during the first 3 months of immediate complete denture wearing, and the average absorption rate of the mandibular alveolar ridge was higher than that of the maxillary ($P < 0.01$). The maxillary alveolar arches tended to become narrow, and the mandibular alveolar arches tended to become wide. The alveolar horizontal absorption was not distinct during the first 3 months of the second complete denture wearing.

There was a negative correlation between the masticatory efficiency and the average rate of alveolar arch absorption of the patients wearing the immediate complete dentures for 3 months. The results suggest that the immediate complete dentures cannot prevent the alveolar ridges from horizontal absorption, and can not change the direction of alveolar horizontal absorption, so the patients must have another pair of complete dentures after 3 months of wearing immediate complete denture.

Key words: alveolar arch dental arch masticatory efficiency immediate complete denture