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·基础研究·

微种植体结合CD矫治器远移上颌磨牙时尖牙位置变化的体外研究

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【摘要】 目的 探讨体外微种植体结合CD矫治器推上颌第一磨牙远中移动时，尖牙三维位置的变化。**方法** 选择10副安氏Ⅱ类错𬌗畸形Typodont模型，随机选取一侧作为实验组，将CD矫治器粘接于实验侧的上颌尖牙与第一磨牙，以直径1.2 mm的不锈钢丝弯制支抗部件，模拟植入颧齿槽嵴的微种植体，并对尖牙施加约180 g的正畸矫治力。而另一侧作为对照组，不加力。随后，在蜡堤模型不同部位植入6个微种植体进行标记，作为实验前后的固定参照物。将Typodont模型放入56 ℃恒温箱中水浴加热2 min，通过3-shape口内扫描仪对实验前、后模型进行全牙列扫描。通过参照物将实验前后的数字模型进行重叠，测量上颌尖牙、第一磨牙三维位置的变化。**结果** 实验组第一磨牙牙冠矢状向（远中）移动距离为（0.25 ± 0.33）mm，垂直向移动距离为（0.25 ± 0.28）mm，与对照组相比差异有统计学意义（$P < 0.05$），而横向变化差异无统计学意义（$P > 0.05$）；实验组第一磨牙牙根根尖位置变化差异无统计学意义（$P > 0.05$）。实验组上颌尖牙牙冠横向移动距离为（4.03 ± 2.11）mm，垂直移动距离为（1.86 ± 1.01）mm，与对照组相比差异有统计学意义（$P < 0.001$），而矢状向变化无统计学差异（$P > 0.05$）；实验组上颌尖牙根尖位置变化差异无统计学意义（$P > 0.05$）。**结论** 微种植体结合CD矫治器远移上颌磨牙时，上颌尖牙牙冠发生颊向倾斜的同时也伴随少量压低。

【关键词】 微种植体；CD矫治器；安氏Ⅱ类错𬌗畸形；支抗；牙齿移动；远中向移动；上颌磨牙；上颌尖牙；三维位置
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Changes in canine position during maxillary molar distalization with mini-implant and CD appliance: an *in vitro* study

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【Abstract】 Objective To investigate changes in the three-dimensional position of the maxillary canine during the distal movement of the maxillary first molar by a mini-implant combined with a CD appliance. **Methods** Ten typodont models of class II malocclusion were selected, and one side was randomly chosen as the experimental group. The CD appliance was bonded to the maxillary canine and first molar of the experimental group, and 1.2 mm stainless steel wire was bent as the anchorage, which was fixed on the model to simulate mini-implants implanted in the zygomatic alveolar ridge. Then, 180 g orthodontic force was applied to the canine of the experimental group; the other side was recognized as the control group and was not used for strengthening. Six mini-implants were implanted in different parts of the model and used as a reference before and after the experiment. The models were placed in an incubator and heated at 56 ℃ in a water bath for 2 min. The models were scanned before and after thermostatic water bath treatment with a 3-shape scanner. Then, the digital models were overlapped through the reference points, and the positions of the canines and first molars were measured before and after the experiment. **Results** The sagittal movement distance of the first molar

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in the experimental group was (0.25 ± 0.33) mm, and the vertical movement distance was (0.25 ± 0.28)mm, which was significantly different from the control group ($P < 0.05$), while the transverse change was not significantly different ($P > 0.05$). There was no significant difference in the root position of the first molar in the experimental group ($P > 0.05$). The lateral and vertical displacement distances of the maxillary canine crown in the experimental group were (4.03 ± 2.11) mm and (1.86 ± 1.01) mm, respectively, which were significantly different from those in the control group ($P < 0.001$), while the sagittal changes showed no significant differences ($P > 0.05$). In the experimental group, there was no significant difference in the position of the apex of the maxillary cusp ($P > 0.05$). **Conclusion**　Our *in vitro* study showed that the maxillary canines inclined buccally accompanied by a small amount of intrusion during molar distalization by a mini-implant combined with a CD appliance.

【Key words】 mini-implant;　CD appliance;　class Ⅱ malocclusion;　anchorage;　tooth movement;　distal movement;　maxillary molars;　maxillary canines;　three-dimensional position

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安氏Ⅱ类错𬌗是临床上常见的错𬌗畸形，推上颌磨牙向远中成为矫治Ⅱ类错𬌗较为常用的方法。迄今为止，国内外已经研制出多种远移上颌磨牙的装置，其中包括摆式矫治器、头帽口外弓、微种植体、透明矫治器、CD（Carrière distalization，CD）矫治器等[1-5]。CD矫治器，即磨牙远移棒，是德国医生Carrière发明的一种针对Ⅱ类错𬌗的简单高效的远移磨牙矫治装置，特别是纠正上颌磨牙近中腭向扭转效果较好[6]。但是，传统远移磨牙矫治器，存在前磨牙前移、前牙唇倾等副作用[7-8]。而微种植体因结构简单，且可以提供有效的绝对支抗，是治疗安氏Ⅱ类非拔牙病例的有效手段[9-10]。因此，许多远移磨牙的矫治装置与微种植体联合使用，避免支抗丧失[11-13]。目前有学者已将CD矫治器与微种植体联合运用[14]。出于医学伦理考虑，笔者只能通过体外试验，探讨CD矫治器联合微种植体远移上颌磨牙时尖牙三维位置的变化，为临床提供一定理论依据。

1　材料和方法

1.1　材料

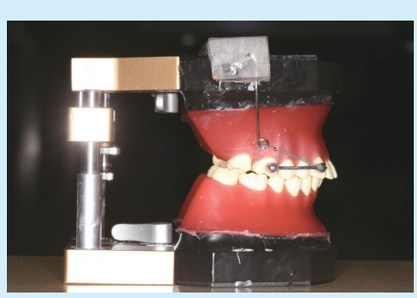
CD矫治器（Masel，美国），安氏Ⅱ类错𬌗畸形Typodont模型10副（YDM-Yamaura，日本），1.2 mm不锈钢丝（上海康桥齿科医械厂），恒温水浴箱（汕头市医用设备厂有限公司）。

1.2　分组

随机选择一侧为实验组，以镍钛拉簧施加约180 g矫治力，另一侧为对照组，不施加矫治力，如图1所示。

1.3　建立远移磨牙模型

将CD矫治器分别粘接于安氏Ⅱ类错𬌗畸形Typodont模型的双侧上颌尖牙与第一磨牙，利用直径为1.2 mm的不锈钢丝弯制支抗部件，于上颌第一、第二磨牙间颊侧龈缘上7 mm模拟植入颧齿槽嵴的微种植体，并通过自凝型基托树脂固定（图1）。



One side of the experimental group was treated with niti tension spring, the other side was the control group, and no corrective power was applied

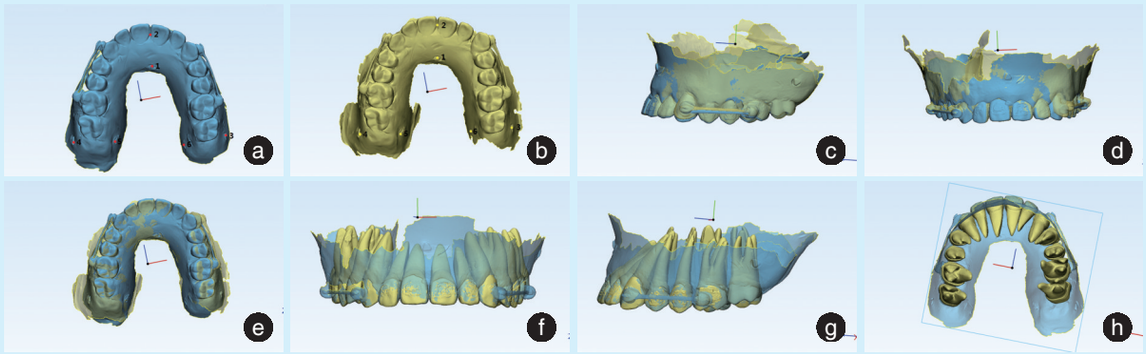
图1　安氏Ⅱ类错𬌗畸形Typodont模型实验装置

Figure 1　Experimental device of the typodont models of class Ⅱ malocclusion

1.4　实验前后模型重叠、配准及测量

在蜡堤模型不同部位植入6个微种植体标记，于56 ℃水浴箱中加热2 min，使用3-shape口内扫描仪对实验前后的上牙列模型进行扫描。将所得数字化模型转化为stl格式，导入3-matic Research 13.0 Beta软件，以标记点进行重叠，将牙齿模型分别与实验前后数字化模型进行重叠，形成完整数字化牙列（包括牙冠、牙根），如图2所示。标记实验前上牙列的中切牙近中切角间点及上颌第一磨牙近中舌尖点，再转移至实验后模型中，分别导入Dolphin Imaging 11.95 Premium后，以标记点建立三维坐标系。以实验前中切牙近中切角间标志

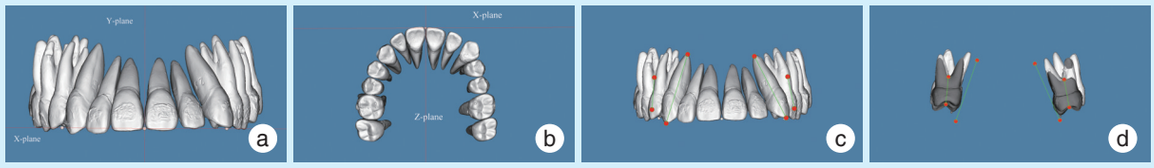
点为原点，过原点与左右第一磨牙近中腭尖点的连线为X平面，过原点且于垂直向垂直于X平面为Y平面，过原点且垂直于X平面和Y平面为Z平面（图3）。由同一研究者标记尖牙牙尖和牙根、第一磨牙牙冠中央窝和根分叉位置，测量两次后取平均值。



a&b: the digital model and reference points before and after the experiment; c-e: the digital models before and after the experiment were overlapped according to the marker points; f-h: after the registration of the tooth model and the digital model, the digital dentition with crown and root was formed

Figure 2　Overlap and registration of digital models before and after the experiment

图2　实验前后模型重叠与配准



a: the X-plane passes through the origin (the midpoint between the maxillary central incisors) and is parallel to the line connecting the mesial palatal cusp tips of the maxillary molars. The Y-plane is perpendicular to the X-plane and passes through the origin; b: the Z-plane is perpendicular to the X-plane and Y-plane, passing through the origin; c: mark on the cusp tip and root apex of the maxillary canine teeth; d: mark on the central fossa and furcation of the maxillary first molar teeth

Figure 3　Establishment of the coordinate system and measurements

图3　坐标系建立与测量

1.5　统计学分析

采用SPSS 24.0软件进行数据分析，各组数据符合正态分布，数据用均数 ± 标准差表示，采用t检验进行分析，$P < 0.05$为差异有统计学意义。

2　结　果

2.1　实验前后上颌第一磨牙在三维空间位置的变化

在矢状向（Z平面）上，实验组第一磨牙牙冠远中移动距离为（0.25 ± 0.33）mm，对照组为（-0.01 ± 0.21）mm，差异有统计学意义（$P < 0.05$）。垂直向（Y平面）上，实验组第一磨牙牙冠移动距离为（0.25 ± 0.28）mm，对照组为（-0.01 ± 0.07）mm，差异有统计学意义（$P < 0.05$）。而第一磨牙牙冠在横向（X平面）变化差异无统计学意义（$P > 0.05$）。牙根位置均未发生明显变化（$P > 0.05$），如表1所示。

2.2　实验前后上颌尖牙在三维空间位置的变化

横向（X平面）上，实验组牙冠颊向移动距离为（4.03 ± 2.11）mm，对照组为（-0.05 ± 0.29）mm，差异有统计学意义（$P < 0.001$）；实验组牙根与对照组牙根变化差异无统计学意义，说明矫治力使尖牙牙冠发生颊向倾斜。垂直向（Y平面）上，实验组牙冠向龈方移动距离为（1.86 ± 1.01）mm，对照组为（-0.07 ± 0.15）mm，差

表1　实验前后上颌第一磨牙在三维空间位置的变化

Table 1　Changes in the three-dimensional position of the maxillary first molar before and after the experiment　$\bar{x} \pm s$, mm

Groups	Xc	Xr	Yc	Yr	Zc	Zr
Experimental group	0.54 ± 1.07	0.17 ± 0.84	0.25 ± 0.28	0.09 ± 0.25	0.25 ± 0.33	0.13 ± 0.33
Control group	-0.09 ± 0.24	-0.04 ± 0.40	-0.01 ± 0.07	-0.03 ± 0.09	-0.01 ± 0.21	0.12 ± 0.18
t	1.186	0.711	2.879	1.434	2.108	0.084
P	0.086	0.486	0.01	0.169	0.049	0.934

Xc: the change of X plane value of maxillary first molar crown; Xr: the change of X plane value of the root; Yc: the change of Y plane value of the crown; Yr: the change of Y plane value of the root; Zc: the change of Z plane value of the crown; Zr: the change of Z plane value of the root

异有统计学意义($P < 0.001$)；实验组牙根与对照组牙根变化差异无统计学意义($P > 0.05$)，说明矫治力对尖牙牙冠产生少量压低作用，牙体可能发生倾斜移动。矢状向(Z平面)上，实验组牙冠与对照组牙冠、实验组牙根与对照组牙根变化差异均无统计学意义($P > 0.05$)。见表2。

表2　实验前后上颌尖牙在三维空间位置的变化

Table 2　Changes in the three-dimensional position of the maxillary canine before and after the experiment　$\bar{x} \pm s$, mm

Groups	Xc	Xr	Yc	Yr	Zc	Zr
Experimental group	4.03 ± 2.11	0.34 ± 2.64	1.86 ± 1.01	-0.31 ± 0.94	0.80 ± 1.15	0.56 ± 0.98
Control group	-0.05 ± 0.29	0.15 ± 1.16	-0.07 ± 0.15	0.03 ± 0.26	0.05 ± 0.32	0.32 ± 0.84
t	6.293	0.201	5.978	-1.044	2.212	0.469
P	< 0.001	0.845	< 0.001	0.324	0.054	0.650

Xc: the change of X plane value of maxillary first molar crown; Xr: the change of X plane value of the root; Yc: the change of Y plane value of the crown; Yr: the change of Y plane value of the root; Zc: the change of Z plane value of the crown; Zr: the change of Z plane value of the root

3　讨　论

微种植体可为内收上切牙、磨牙远移提供较强支抗[15-16]。CD矫治器能防止磨牙过度远中倾斜及扭转，尽量让后牙整体远中移动[6]。因此，可联合使用微种植体与CD矫治器矫治安氏Ⅱ类错𬌗。CD矫治器对磨牙的作用已有相关研究[14]，但目前未见其对尖牙作用的报道。本研究发现在微种植体联合CD矫治器远移磨牙过程中，尖牙的三维位置也发生变化。

本实验所用蜡堤在水浴温度高于60 ℃时出现部分溶解；低于52 ℃则牙齿位置变化不明显，所以本实验水浴温度选择56 ℃。同时，当水浴时间大于150 s时，尖牙颊向移动过大，有部分牙齿出现脱位情况，因此，水浴时间控制在2 min。同时通过牙列三维重叠，可获得治疗前后每个牙齿的三维空间位置的变化[17]。上颌模型重叠常需要腭皱或较为固定的解剖结构作为参照点[18-19]。但是，蜡堤表面过于光滑，口内扫描仪无法扫描至基托部，故以6颗微种植体植入不同部位作为重叠标志点。为减小误差，在重叠过程中，以6个标志点同时配准。如果有个别标记点偏移较多，说明该标志点移位。但在实验过程中，未发生个别标志点偏移，说明该方法可以作为实验前后重叠比较。

3.1　CD矫治器对磨牙的远移作用

在本研究中，第一磨牙的牙冠在矢状向及垂直向上有少量移动，但是无临床意义，说明CD矫治器磨牙远移效果有待进一步验证。该结果可能与矫治器的设计有关，CD矫治器主要对上颌磨牙近中腭向扭转的纠正效果较为明显。

3.2　CD矫治器对尖牙的远移作用(矢状向)

本研究通过弯制不锈钢丝作为支抗部件，模拟临床常用的微种植体，并与CD矫治器联合使用，让上颌尖牙、前磨牙和第一磨牙作为一个运动单位，利用镍钛拉簧，由支抗部件直接向CD矫治器的尖牙部分加力，可避免因Ⅱ类牵引而导致的下前牙唇倾，下颌也可不必使用复杂矫治装置如舌弓或其他活动保持器以提供支抗，导致下切牙唇倾及下颌位不稳等不良反应。通过有限元分析表明，150~200 g载荷力为较理想的正畸牵引力[20]。因此，本实验使用180 g载荷。研究结果表明，CD矫治器虽然使尖牙产生少量远中移动，但其距离有限，且远移效果远不及横向和垂直向移动效果。这可能与本实验设计未拔除上颌第二磨牙有关，第一磨牙远移过程中受到较大阻力。

3.3　CD矫治器对尖牙的压低作用(垂直向)

本研究通过模拟植于颧齿槽嵴的微种植体作

为支抗部件，其位于尖牙的远中龈方。因此，对尖牙除了产生远中作用力外，还存在垂直向分力。结果表明垂直向上，尖牙牙冠向龈方移动约1.8 mm。虽然就CD矫治器设计而言，近中段龈向移动空间并不大，且垂直向分力小于矢状向分力，上颌尖牙的压低应较为困难。但结果发现尖牙压低效果较远移效果明显，这可能与模拟微种植体的位置及尖牙的颊向倾斜有关。

3.4　CD矫治器对尖牙的颊倾作用（横向）

本研究采用的模拟微种植体结合CD矫治器远移磨牙时，尖牙产生了明显的颊向倾斜。其原因可能是：①模拟的微种植体位于尖牙颊侧，施加矫治力时对其有颊向作用力，尖牙有颊向倾斜的趋势；②CD矫治器的“关节窝”与远移棒为活动连接，“关节窝”与远移棒之间水平活动空间约45°，垂直活动空间为15°，让上颌第一磨牙围绕腭根远中旋转移动的同时，尖牙有颊向移动的可能。如果磨牙未能向远中明显旋转，则尖牙在矫治力的作用下，就可能产生颊向移动，正如本实验所示。因此，在矫治力作用下，上颌尖牙更容易产生颊向移动。

本研究发现，上颌尖牙颊向倾斜的同时也伴随少量压低，而其远中移动差异无统计学意义。因此，临床上在使用CD矫治器推磨牙向远中时，应注意尖牙三维位置，尤其是横向的变化，避免出现不希望的牙齿移动，但口内情况仍需进一步临床验证。

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