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· 临床研究 ·

# 隐形矫治成人非拔牙患者出现下颌中切牙区开放性龈楔状隙的危险因素

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【摘要】 **目的**　探究使用无托槽隐形矫治器治疗成人非拔牙患者后下颌中切牙区开放性龈楔状隙的发生率和危险因素，为预防正畸治疗后切牙区开放性龈楔状隙的发生提供参考。**方法**　本研究已通过单位医学伦理委员会审查批准，并获得患者知情同意。选择2022年9月至2024年12月在合肥市口腔医院接受无托槽隐形矫治结束未拔牙成人错𬌗畸形的125例患者为研究对象，根据矫治结束即刻正面口内照中切牙区开放性龈楔状隙的有无，将患者分为正常组和开放性龈楔状隙组。根据治疗前后的口内照片、数字化模型、锥形束CT等临床资料，测量患者下颌切牙区牙冠的重叠和旋转、牙冠形态、附件数量和邻面去釉量(interproximal enamel reduction，IPR)等指标并进行分析。**结果**　使用无托槽隐形矫治器治疗成人患者矫治结束后上颌与下颌的中切牙间开放性龈楔状隙发生率分别为28.8%和39.2%。下颌中切牙区正常组和开放性龈楔状隙组的性别、安氏分类、牙龈生物型、覆𬌗、覆盖、邻面去釉量、年龄、矫治周期、牙长轴成角、下颌中切牙在治疗前后水平移动的距离差异无统计学意义($P$>0.05)，两组在附件数量、近中切角间前后向距离、中切牙近中邻接点(interproximal contact point，ICP)至牙槽嵴顶的距离(alveolar bone crest，ABC)的距离(ICP-ABC)、相邻两个中切牙近中釉牙骨质界(mesial cementoenamel junction，CEJ)间的水平距离(CEJ-CEJ)和唇侧牙槽骨厚度上差异具有统计学意义($P$<0.05)。其中邻面去釉量和下前牙压低量与开放性龈楔状隙的严重程度有关($P$<0.05)。回归分析显示，附件数量、近中切角间前后向距离、ICP-ABC距离、CEJ-CEJ水平距离与开放性龈楔状隙发生显著相关。**结论**　成人患者使用无托槽隐形矫治器后下颌中切牙区开放性龈楔状隙发生率较高，附件数量为2、近中切角间前后向距离、牙邻接点至牙槽嵴顶间的距离以及相邻釉牙骨质界间的水平距离为矫治结束后出现开放性龈楔状隙的危险因素。

【关键词】 正畸治疗；　无托槽隐形矫治；　成人非拔牙矫治；　红白美学；　切牙区；　开放性龈楔状隙；　邻面去釉；　正畸附件；　三维测量；　移动距离；　牙周表型

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**Risk factors for open gingival embrasures in the mandibular central incisor region among adult non-extraction patients treated with clear aligner therapy**

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【Abstract】 **Objective**　To investigate the incidence and risk factors of open gingival embrasures (OGEs) in the incisor region after treatment with clear aligners in adult non-extraction patients and provide a reference for preventing the

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occurrence of an open gingival wedge gap in the incisal area after orthodontic treatment. **Methods** This study has been reviewed and approved by the institutional medical ethics committee, and informed consent was obtained from the patients. A total of 125 adult patients with malocclusion who completed clear aligner treatment at Hefei Stomatological Hospital from September 2022 to December 2024 were selected as the study subjects. Based on the presence or absence of OGEs in the incisor region observed in frontal intraoral photographs taken immediately after treatment completion, the patients were divided into a normal group and an OGE group. Clinical data, including intraoral photographs, digital models, and cone-beam computed tomography before and after treatment, were analyzed. Measurements such as incisor overlap and rotation, crown morphology, number of attachments, and interproximal enamel reduction (IPR) were recorded and analyzed. **Results** The incidence of OGEs between the maxillary and mandibular central incisors after clear aligner treatment in adult patients was 28.8% and 39.2%, respectively. No statistically significant differences were observed between the normal and OGE groups in terms of sex, Angle′s classification, gingival biotype, overbite, overjet, IPR amount, age, treatment duration, tooth axis angulation, or horizontal movement distance of mandibular central incisors before and after treatment ($P > 0.05$). However, significant differences were found in the number of attachments, anteroposterior distance between mesial incisal angles, distance from the interproximal contact point (ICP) to the alveolar bone crest (ABC) (ICP-ABC), horizontal distance between mesial cementoenamel junction (CEJ) of two adjacent central incisors (CEJ-CEJ) and labial alveolar bone thickness ($P < 0.05$). IPR amount and mandibular incisor intrusion were significantly associated with the severity of OGEs ($P < 0.05$). Regression analysis revealed that the number of attachments, anteroposterior distance between mesial incisal angles, ICP-ABC distance, and CEJ-CEJ horizontal distance were significantly correlated with the occurrence of OGEs. **Conclusion** The incidence of open gingival embrasures in the mandibular central incisor region is relatively high among adult patients treated with clear aligners. The number of attachments ($n = 2$), the anteroposterior distance between the mesio-incisal angles, the distance from the tooth contact point to the alveolar bone crest, and the horizontal distance between adjacent cementoenamel junctions have been identified as risk factors for the development of open gingival embrasures upon completion of orthodontic treatment.

**【Key words】** orthodontic treatment; clear aligner; adult non-extraction treatment; red and white aesthetics; incisor area; open gingival wedge-shaped gap; glaze the adjacent surface; orthodontic accessories; three-dimensional measurement; moving distance; periodontal phenotype

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**【Competing interests】** The authors declare no competing interests.

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开放性龈楔状隙(open gingival embrasure)又称为黑三角,是指相邻牙齿间的牙龈乳头未能完全覆盖龈楔状隙而形成的三角形间隙,成人正畸患者治疗后开放性龈楔状隙的发生率较高[1]。研究显示使用无托槽隐形矫治器治疗的成人非拔牙患者较使用固定矫治器的成人非拔牙患者开放性龈楔状隙发生率高[2],固定矫治器通过金属弓丝对牙齿施加连续的轻力[3],而无托槽隐形矫治器施加瞬时和过度的初始应力,可能导致牙周组织的病理反应[4]。本研究拟探究采用无托槽隐形矫治器治疗成人非拔牙患者下颌中切牙区发生开放性龈楔状隙的危险因素,并对危险因素进行深入分析,为后期预防正畸治疗后下颌中切牙区开放性龈楔状隙的发生提供依据。

## 1 资料和方法

### 1.1 研究对象

本回顾性研究获得合肥市口腔医院医学伦理委员会批准(Y20240155),所有患者均签署了知情同意书。选取2022年9月至2024年12月在合肥市口腔医院无托槽隐形矫治结束的成人错𬌗畸形患者125例。纳入标准为:①开始正畸治疗时年龄在18岁及以上;②使用无托槽隐形矫治器并且未拔牙;③治疗开始时无牙周病史和开放性龈楔状隙;④治疗前后均有完整清晰的口内照片、影像学资料和口扫数字模型;⑤除第三磨牙外无牙列缺损。排除标准为:①牙周病患者;②治疗前中切牙存在修复体;③治疗期间接受正颌治疗或牙周手术;④长期用药史或使用过影响牙龈状况的药物;⑤影响牙周组织健康或骨代谢的系统性疾病(如未控

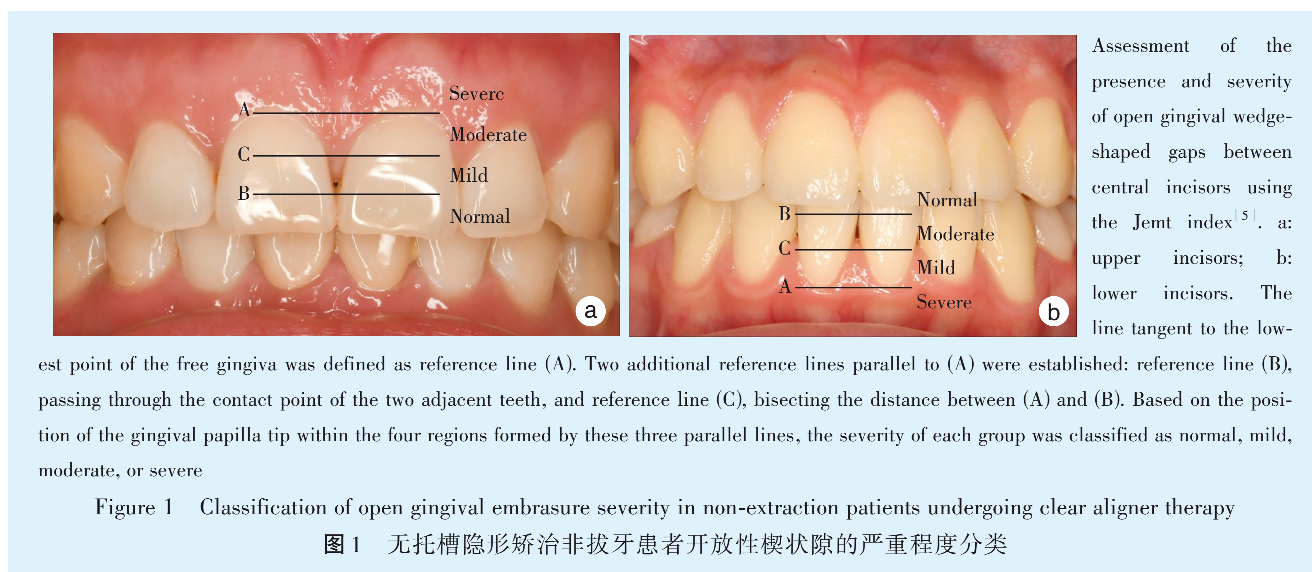
制的糖尿病、骨质疏松症等)；⑥既往正畸治疗史。

### 1.2　数据收集

收集所有纳入对象在矫正前后使用锥形束CT(cone-beam computed tomography CBCT)，专业摄像机和iTero激光扫描仪记录的患者数字化图像模型。利用Clincheck(Align Technology，California公司，美国)软件收集研究对象隐形治疗方案中邻面去釉量和附件数量，Clincheck软件设计的邻面去釉量与口内牙釉质磨除量一致(治疗方案均由一位主任医师进行设计，并由固定团队人员进行临床操作)。记录纳入患者的性别、年龄以及从开始矫治到结束矫治的矫治周期。

### 1.3　数据测量

1.3.1　口内照片测量项目　根据正畸治疗前即刻拍摄的口内照片确定研究对象的安氏分类和上下颌中切牙之间是否存在开放性龈楔状隙。采用Jemt指数评估上下颌中切牙之间开放性龈楔状隙的存在及开放性龈楔状隙的严重程度(正常、轻度、中度和重度)[5](图1)。根据国外De Rouck等[6]的研究，将本研究对象的牙龈生物型分为A1型(薄扇形)、A2型(厚扇形)和B型(厚平形)。




Assessment of the presence and severity of open gingival wedge-shaped gaps between central incisors using the Jemt index[5]. a: upper incisors; b: lower incisors. The line tangent to the lowest point of the free gingiva was defined as reference line (A). Two additional reference lines parallel to (A) were established: reference line (B), passing through the contact point of the two adjacent teeth, and reference line (C), bisecting the distance between (A) and (B). Based on the position of the gingival papilla tip within the four regions formed by these three parallel lines, the severity of each group was classified as normal, mild, moderate, or severe

Figure 1　Classification of open gingival embrasure severity in non-extraction patients undergoing clear aligner therapy

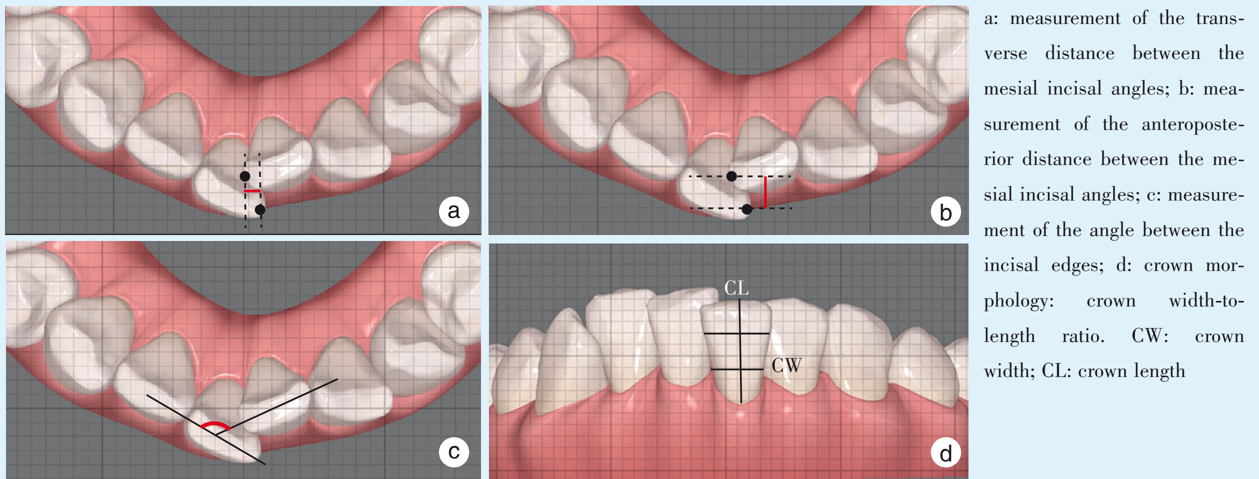
图1　无托槽隐形矫治非拔牙患者开放性楔状隙的严重程度分类

1.3.2　数字化牙齿模型测量项目　从ClinCheck(Align Technology，California，美国)和Dolphin Imaging Software (Dolphin Imaging & Management Solutions，美国)软件中获取数字模型的预处理照片。将这些预处理照片导入ImageJ软件(美国国立卫生研究院)中进行分析。以通过下颌双侧第一磨牙近中接触点的直线做垂直平分线构建基准线，下颌中切牙近中切角间的横向和前后向距离分别定义为垂直和平行于基准线的横向重叠距离(图2a)和前后重叠距离(图2b)。旋转角度定义为下颌中切牙切端之间的夹角(图2c)。在处理后的数字模型中评估中切牙的冠状形态，以冠宽(crown width，CW)和冠长(crown length，CL)之比表示(图2d)。冠长为牙龈顶部至牙冠切端中部的距离，然后将冠长平均分为切1/3、中1/3和颈1/3三部分，冠宽定义为中1/3和颈1/3交界处的近远端距离。

通过下颌前牙牙冠总宽度与现有牙弓长度之间的差值来测量拥挤程度，并依据测量的数据分为轻度拥挤(<4 mm)、中度拥挤(4~8 mm)和重度拥挤(>8 mm)。对矫治前数字模型上前牙区的覆𬌗情况进行判定，将其分为正常、Ⅰ°深覆𬌗、Ⅱ°深覆𬌗和Ⅲ°深覆𬌗。对矫治前数字模型上前牙区的覆盖情况进行测量，将其分为正常、Ⅰ°深覆盖、Ⅱ°深覆盖和Ⅲ°深覆盖。

1.3.3　CBCT测量项目　收集研究对象矫治结束即刻的CBCT影像并以Dicom格式导入Mimics21.0软件(version 21，Materialize公司，比利时)进行三维测量。调整坐标轴，在水平面上将绿色坐标轴调整至下颌双侧中切牙中间的解剖中线位置，同时使橙色坐标轴贯穿两中切牙的牙髓腔(图3a)。在矢状面将橙色与红色坐标轴同步调整至下颌中切牙长轴中心位置(图3b)，获取下颌中切牙的标准冠状面图像(图3c)。

牙长轴成角定义为冠状面上双侧下颌中切牙

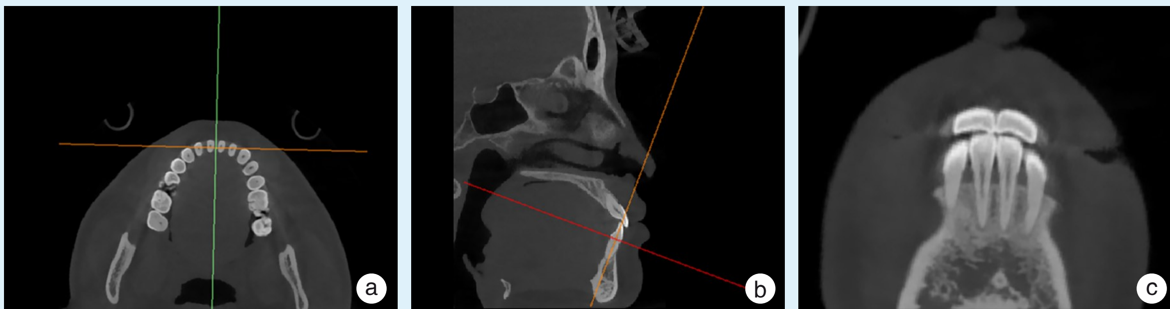



a: measurement of the transverse distance between the mesial incisal angles; b: measurement of the anteroposterior distance between the mesial incisal angles; c: measurement of the angle between the incisal edges; d: crown morphology: crown width-to-length ratio. CW: crown width; CL: crown length

Figure 2 Digital model measurement in the mandibular central incisor region

图2 下颌中切牙区的数字化牙齿模型测量项目

长轴之间的夹角(图4a),正值代表成角在冠方;ICP-ABC距离代表中切牙近中邻接点(interproximal contact point,ICP)至牙槽嵴顶的距离(alveolar bone crest,ABC)(图4b);CEJ-CEJ水平距离代表相邻两个中切牙近中釉牙骨质界(mesial cementoenamel junction,CEJ)间的距离(图4c),唇侧牙槽骨厚度定义为矢状面上通过牙齿唇舌侧CEJ做参考线,在参考线根方2 mm处做一条平行的引导线,在此引导线所在的平面进行测量[7]。




a: horizontal reference plane; b: sagittal reference plane; c: coronal reference plane

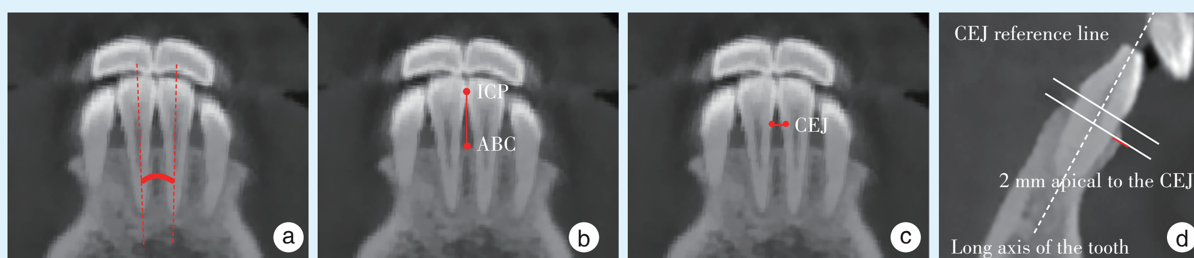
Figure 3 Identification procedure applied to select the measurement plane in the mandibular central incisor region

图3 下颌中切牙区测量平面的确定步骤

1.3.4 CBCT重叠测量项目 应用Mimics21.0软件,以Dicom格式导入研究对象矫治开始和结束即刻的CBCT影像,进行颅骨重叠及三维定位,分别在术前术后的3D模型上选取双侧颏孔[8]以及较明显的颏棘点为特征点,进行颌骨的重叠,建立三维坐标系定位头颅的位置。坐标原点选择颏下点,XY平面选取颏下点以及双侧下颌角下缘点三点构建的下颌平面,Y轴定义为过原点及双侧下颌角下缘点连线的中点,指向舌侧,Z轴定义为过原点垂直于XY平面,指向冠方,由此得到测量的三维坐标系。以牙冠切端与牙根根尖连线为牙长轴,从矢状面观,倾斜度变化定义为矫治前后下颌中切牙牙长轴与下颌平面间角度的变化,记为△IMPA;从矢状面观,计算下颌中切牙的Y轴和Z轴差值即可得出下颌中切牙在治疗前后水平向和垂直向移动的距离,分别定义为L1垂直移动距离和L1水平移动距离。若矫治后下颌中切牙唇向移动、伸长,则上述值记为正(图5)。

1.4 统计学分析

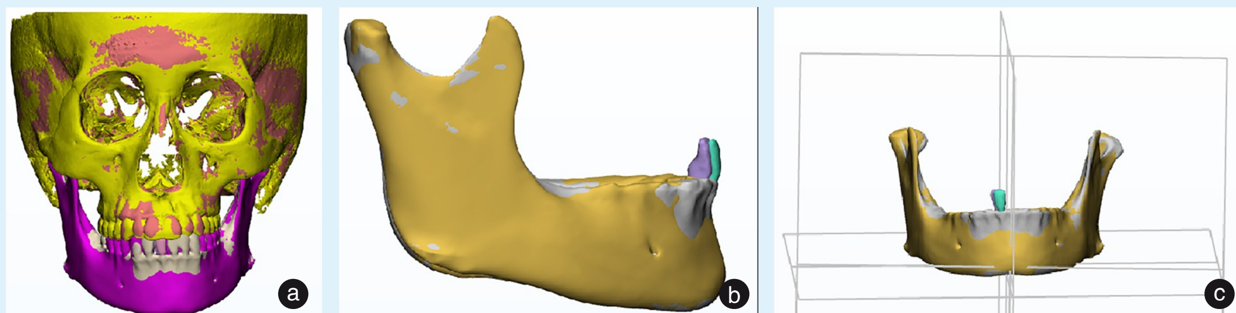
采用组内相关系数(intraclass correlation coefficient,ICC)检验评估测量结果的一致性。所有影像学和模型测量均由一名不知晓患者分组情况的




a: measurement of the angle between tooth long axes; b: measurement of the ICP-ABC distance, ICP: interproximal contact point, ABC: alveolar bone crest; c: measurement of the distance from left CEJ of right central incisor to right CEJ of left central incisor, CEJ: cementoenamel junction; d: measurement of the labial alveolar bone thickness

Figure 4 Cone beam CT radiographic measurement in the mandibular central incisor region

图4 下颌中切牙区锥形束CT测量项目




a: superimposed pre- and post-treatment maxillary tracings; b: superimposed mandibular and anterior tooth tracings; c: establishment of a three-dimensional coordinate system

Figure 5 Maxillary and mandibular anterior teeth fitting degree and establishment of three-dimensional coordinates

图5 下颌骨和下前牙拟合程度及建立三维坐标

研究员完成。为确定评分者的可重复性，该测量者将同一指标重复测量2次，每次测量间隔2周。组内相关系数均>0.9，一致性好。采用SPSS27.0（IBM公司，美国）对数据进行统计学分析，分类变量用$n$（%）表示，采用卡方检验；连续变量经正态分布检验和方差齐性检验后，若服从正态分布且方差齐，则用均数±标准差表示，采用独立样本$t$检验，若服从正态分布但方差不齐，则采用$t'$检验，若不服从正态分布，则采用Mann-Whitney $U$检验。对所有变量进行单因素二分类logistic回归分析，将$P$<0.10的变量纳入多因素logistic回归模型（采用Enter法），以确定独立危险因素。检验水准$\alpha$=0.05，所有检验均为双侧检验。

## 2 结 果

### 2.1 开放性龈楔状隙的发生率

125例研究对象无托槽隐形矫治结束后，36例患者上颌中切牙区出现开放性龈楔状隙，上颌开放性龈楔状隙的总发生率为28.8%，其中轻度的发生率为22.4%，中度的发生率为6.4%。49例患者下颌中切牙区出现开放性龈楔状隙，下颌开放性龈楔状隙的总发生率为39.2%，其中轻度的发生率为27.2%，中度的发生率为12.0%。上下颌均未见重度开放性龈楔状隙。

### 2.2 正常组和开放性龈楔状隙组基线资料的比较

分类变量中，正常组和开放性龈楔状隙组的性别、安氏分类、牙龈生物型、覆𬌗、覆盖、邻面去釉量和附件数量差异无统计学意义（$P$>0.05），两组患者拥挤度差异具有统计学意义（$P$<0.05）（表1）。开放性龈楔状隙轻度组和中度组的性别、安氏分类、牙龈生物型、拥挤、覆𬌗、覆盖、附件数量差异无统计学意义（$P$>0.05），两组患者邻面去釉量差异具有统计学意义（$P$<0.05）（表2）

连续变量中，正常组和开放性龈楔状隙组的年龄、矫治周期、切缘间角度、牙冠形态（冠宽比）、牙长轴成角、L1水平移动距离差异无统计学意义

($P$>0.05),而近中切角间前后向和横向距离、ICP-ABC距离、CEJ-CEJ水平距离、唇侧牙槽骨厚度、△IMPA、L1垂直移动距离差异具有统计学意义($P$<0.05)(表3)。开放性龈楔状隙轻度组和中度组的年龄、矫治周期、近中切角间前后向和横向距离、切缘间角度、牙冠形态、牙长轴成角、唇侧牙槽骨厚度、△IMPA和L1水平移动距离差异无统计学意义($P$>0.05),但两组患者ICP-ABC距离、CEJ-CEJ水平距离、L1垂直移动距离差异具有统计学意义($P$<0.05)(表4)。

**表1** 成人非拔牙患者无托槽隐形矫治下颌中切牙区正常组和开放性龈楔状隙组分类变量的比较

Table 1 Comparison of categorical variables between the normal group and the open gingival embrasure group of the mandibular central incisor region in adult non-extraction patients undergoing clear aligner therapy n(%)

| Categorical variable | Normal group ($n$=76) | Open gingival embrasure group ($n$=49) | $\chi^2$ | $P$ |
|---|---|---|---|---|
| Gender | | | 0.38 | 0.538 |
| Male | 11(14.5) | 4(8.2) | | |
| Female | 65(85.5) | 45(91.8) | | |
| Malocclusion | | | 0.57 | 0.751 |
| Class I | 32(42.1) | 22(44.9) | | |
| Class II | 41(54.0) | 25(51.0) | | |
| Class Ⅲ | 3(3.9) | 2(4.1) | | |
| Gingival biotype | | | 0.38 | 0.828 |
| A1 | 28(36.8) | 19(38.8) | | |
| A2 | 42(55.3) | 27(55.1) | | |
| B | 6(7.9) | 3(6.1) | | |
| Crowding | | | 9.21 | 0.010 |
| <4 mm | 54(71.1) | 23(46.9) | | |
| 4−8mm | 20(26.3) | 24(49.0) | | |
| >8 mm | 2(2.6) | 2(4.1) | | |
| Overbite | | | 1.75 | 0.625 |
| Normal | 24(31.6) | 17(34.7) | | |
| I | 35(46.1) | 21(42.9) | | |
| II | 14(18.4) | 8(16.3) | | |
| Ⅲ | 3(3.9) | 3(6.1) | | |
| Overjet | | | 1.33 | 0.721 |
| Normal | 23(30.3) | 16(32.7) | | |
| I | 39(51.3) | 23(46.9) | | |
| II | 12(15.8) | 9(18.4) | | |
| Ⅲ | 2(2.6) | 1(2.0) | | |
| IPR in central incisors | | | 0.69 | 0.407 |
| 0 mm | 40(52.6) | 30 (61.2) | | |
| >0 mm | 36(47.4) | 19 (38.8) | | |
| Attachments in central incisors | | | 5.38 | 0.068 |
| 0 | 63(82.9) | 35(71.4) | | |
| 1 | 9(11.8) | 6(12.3) | | |
| 2 | 4(5.3) | 8(16.3) | | |

IPR: interproximal enamel reduction

### 2.3 影响下颌中切牙区开放性龈楔状隙发生因素的回归分析

经过单因素回归分析后发现,以下因素对于矫治结束后下颌中切牙区出现开放性龈楔状隙存在重要影响:附件数量、近中切角间前后向距离、近中切角间横向距离、切缘间角度、ICP-ABC距离、CEJ-CEJ距离、唇侧牙槽骨厚度、△IMPA和L1垂直移动距离(表5)。多因素Logistic回归分析显示,

表2　成人非拔牙患者无托槽隐形矫治下颌中切牙区开放性龈楔状隙轻度组与中度组分类变量的比较

Table 2　Comparison of categorical variables between the mild and moderate open gingival embrasure groups of the mandibular central incisor region in adult non-extraction patients undergoing clear aligner therapy　$n(\%)$

| Categorical variable | Mild group ($n$=34) | Moderate group ($n$=15) | $\chi^2$ | $P$ |
|---|---|---|---|---|
| Gender | | | 0.01 | >0.999 |
| Male | 3(8.8) | 1(6.7) | | |
| Female | 31(91.2) | 14(93.3) | | |
| Malocclusion | | | 0.19 | 0.911 |
| Class I | 16(47.1) | 6(40.0) | | |
| Class II | 17(50.0) | 8(53.3) | | |
| Class III | 1(2.9) | 1(6.7) | | |
| Gingival biotype | | | 0.36 | 0.837 |
| A1 | 14(41.2) | 5(33.3) | | |
| A2 | 18(52.9) | 9(60.0) | | |
| B | 2(5.9) | 1(6.7) | | |
| Crowding | | | 0.51 | 0.774 |
| <4 mm | 17(50.0) | 6(40.0) | | |
| 4-8 mm | 16(47.1) | 8(53.3) | | |
| >8 mm | 1(2.9) | 1(6.7) | | |
| Overbite | | | 2.21 | 0.531 |
| Normal | 13(38.2) | 4(26.7) | | |
| I | 15(44.1) | 6(40.0) | | |
| II | 5(14.7) | 3(20.0) | | |
| III | 1(3.0) | 2(13.3) | | |
| Overjet | | | 1.63 | 0.652 |
| Normal | 12(35.3) | 4(26.7) | | |
| I | 16(47.1) | 7(46.6) | | |
| II | 5(14.7) | 4(26.7) | | |
| III | 1(2.9) | 0(0) | | |
| IPR in central incisors | | | 5.80 | 0.016 |
| 0 mm | 17(50.0) | 13(86.7) | | |
| >0 mm | 17(50.0) | 2(13.3) | | |
| Attachments in central incisors | | | 1.90 | 0.386 |
| 0 | 26(76.4) | 9(60.0) | | |
| 1 | 4(11.8) | 2(13.3) | | |
| 2 | 4(11.8) | 4(26.7) | | |

IPR：interproximal enamel reduction

附件数量为2、近中切角间前后向距离、ICP-ABC距离、CEJ-CEJ距离是矫治结束后下颌中切牙间出现开放性龈楔状隙的独立危险因素（$P<0.05$）。

## 3 讨　论

开放性龈楔状隙是正畸治疗后最常见的不良反应之一，特别是在成人前牙区最容易出现，影响口腔的红白美学及口腔软硬组织健康。有研究显示使用无托槽隐形矫治器可以有效减轻正畸过程中的疼痛程度，另外，无托槽隐形矫治器的美观性和隐形性有助于降低正畸患者的焦虑水平[9]。基于以上特征，越来越多成人正畸患者倾向于选择无托槽隐形矫治器，因此对成年正畸非拔牙患者使用无托槽隐形矫治器治疗后出现开放性龈楔状隙的危险因素和防治方法的研究具有重要的意义。

本研究结果显示，患者的年龄、性别与下颌中切牙区开放性龈楔状隙的出现没有显著关系。目前关于年龄和开放性龈楔状隙发生关联性的研究结果不一致[10-11]，这种差异可能是由于研究对象的纳入标准和排除标准不同，由于本研究只纳入了

**表3**　成人非拔牙患者无托槽隐形矫治下颌中切牙区正常组和开放性龈楔状隙组连续变量的比较

Table 3　Comparison of continuous variables between the normal group and the open gingival embrasure group of the mandibular central incisor region in adult non-extraction patients undergoing clear aligner therapy　$\bar{x}\pm s$

| Continuous variable | Normal group (*n*=76) | Open gingival embrasure group (*n*=49) | *t*/*Z* | *P* |
|---|---|---|---|---|
| Age/years | 25.32±6.78 | 27.12±5.92 | 1.53 | 0.128 |
| Treatment duration/months | 28.58±11.83 | 29.42±12.28 | 0.36 | 0.721 |
| Anteroposterior distance between the mesioincisal angles/mm | 0.38±0.54 | 0.67±0.71 | 2.14 | 0.032 |
| Transverse distance between the mesioincisal angles/mm | 0.42±0.51 | 0.78±0.95 | 2.37 | 0.018 |
| Angle between the incisal edges/° | 164.70±9.44 | 165.00±6.99 | 0.14 | 0.892 |
| Crown ratio (tooth shape) | 0.71±0.08 | 0.64±0.07 | 1.40 | 0.164 |
| Root angulation/° | −2.15±4.39 | −2.48±5.02 | 1.68 | 0.095 |
| Distance from ICP to ABC/mm | 5.18±0.59 | 5.96±1.15 | 2.54 | 0.011 |
| Right CEJ-left CEJ distance/mm | 1.48±0.38 | 1.82±0.47 | 2.41 | 0.016 |
| Labial alveolar bone thickness/mm | 0.43±0.38 | 0.41±0.40 | 1.97 | 0.049 |
| △IMPA/° | 8.72±9.86 | 4.95±5.81 | 2.18 | 0.029 |
| Vertical movement of L1/mm | 1.42±1.68 | 2.51±1.62 | 2.51 | 0.012 |
| Horizontal movement of L1/mm | 1.68±1.52 | 1.73±1.61 | 0.18 | 0.854 |

ICP: interproximal contact point; ABC: alveolar bone crest; CEJ: mesial cementoenamel junction; △IMPA: changes in the angle between the mandibular central incisor long axis and the mandibular plane before and after treatment; L1: mandibular central incisor

**表4**　成人非拔牙患者无托槽隐形矫治下颌中切牙区开放性龈楔状隙轻度组与中度组连续变量的比较

Table 4　Comparison of continuous variables between the mild and moderate open gingival embrasure groups of the mandibular central incisor region in adult non-extraction patients undergoing clear aligner therapy　$\bar{x}\pm s$

| Continuous variable | Mild group (*n*=34) | Moderate group (*n*=15) | *t*/*Z* | *P* |
|---|---|---|---|---|
| Age/years | 26.82±6.12 | 27.88±5.28 | 0.55 | 0.584 |
| Treatment duration/months | 29.12±12.03 | 30.18±13.12 | 0.28 | 0.782 |
| Anteroposterior distance between the mesioincisal angles/mm | 0.62±0.67 | 0.78±0.82 | 0.81 | 0.423 |
| Transverse distance between the mesioincisal angles/mm | 0.71±0.88 | 0.92±1.08 | 0.72 | 0.476 |
| Angle between the incisal edges/° | 164.95±6.73 | 165.12±7.38 | 0.37 | 0.712 |
| Crown ratio (tooth shape) | 0.65±0.08 | 0.63±0.06 | 0.87 | 0.387 |
| Root angulation/° | −2.36±4.88 | −2.75±5.38 | 0.25 | 0.801 |
| Distance from ICP to ABC/mm | 5.78±1.06 | 6.52±1.28 | 2.10 | 0.036 |
| Right CEJ-left CEJ distance/mm | 1.75±0.44 | 2.03±0.53 | 2.04 | 0.041 |
| Labial alveolar bone thickness/mm | 0.40±0.39 | 0.43±0.41 | 0.32 | 0.752 |
| △IMPA/° | 5.28±5.95 | 4.12±5.38 | 0.61 | 0.548 |
| Vertical movement of L1/mm | 2.35±1.58 | 3.18±1.79 | 2.01 | 0.044 |
| Horizontal movement of L1/mm | 1.70±1.58 | 1.81±1.68 | 0.21 | 0.834 |

ICP: interproximal contact point; ABC: alveolar bone crest; CEJ: mesial cementoenamel junction; △IMPA: changes in the angle between the mandibular central incisor long axis and the mandibular plane before and after treatment; L1: mandibular central incisor

成年牙周健康的患者，可能排除了年龄对开放性龈楔状隙发生的影响。本研究纳入的研究对象中女性占比超过80%，显著高于男性，并对各组性别进行统计学分析时未发现组间差异具有统计学意义，Logistic回归分析结果也提示性别并非开放性龈楔状隙的独立危险因素。

有研究认为厚龈生物型患者在正畸治疗中，牙龈退缩的发生率较低，不易出现开放性龈楔状隙[12]，薄龈生物型患者在正畸过程中出现牙周问题的风险更大[13-14]。本研究回归分析结果表明牙龈生物型不是开放性龈楔状隙形成的危险因素，存在这种差异可能是因为本研究对于牙龈生物型的分类主要来自患者的影像学资料，分类存在误差及主观性，在之后的研究中可以采用更加精准的测量方法来进行牙龈生物型的分类[15]。

在本研究中没有发现邻面去釉（interproximal

**表5** 单因素和多因素分析危险因素与成人非拔牙患者无托槽隐形矫治下颌中切牙区开放性龈楔状隙的关系
Table 5 Univariate and multivariate analysis of risk factors for open gingival embrasure in the mandibular central incisor region in adult non-extraction patients undergoing clear aligner therapy

| Variables | Univariate analysis | | *P* | Multifactor analysis | | *P* |
|---|---|---|---|---|---|---|
| | OR | 95%*CI* | | OR | 95%*CI* | |
| Crowding(ref. <4 mm) | | | | | | |
| 4-8mm | 2.71 | 1.35-5.44 | 0.005 | 1.72 | 0.68-4.35 | 0.256 |
| >8 mm | 2.17 | 0.30-15.73 | 0.443 | 1.38 | 0.16-11.82 | 0.768 |
| Attachments in central incisors(ref. 0) | | | | | | |
| 1 | 0.82 | 0.20-3.31 | 0.778 | 0.65 | 0.14-2.98 | 0.578 |
| 2 | 11.44 | 1.38-94.86 | 0.024 | 8.94 | 1.05-76.15 | 0.045 |
| Anteroposterior distance between the mesioincisal angles/mm | 1.58 | 1.09-2.29 | 0.016 | 1.52 | 1.03-2.24 | 0.035 |
| Transverse distance between the mesioincisal angles/mm | 1.72 | 1.02-2.91 | 0.042 | 1.35 | 0.73-2.49 | 0.339 |
| Distance from ICP to ABC/mm | 2.86 | 1.68-4.87 | <0.001 | 2.18 | 1.15-4.13 | 0.017 |
| Right CEJ-left CEJ distance/ mm | 2.58 | 1.38-4.82 | 0.003 | 2.05 | 1.02-4.12 | 0.044 |
| Labial alveolar bone thickness/mm | 1.12 | 1.01-1.24 | 0.049 | 1.05 | 0.96-1.15 | 0.312 |
| △IMPA/ ° | 0.96 | 0.92-0.99 | 0.032 | 0.97 | 0.93-1.02 | 0.261 |
| Vertical movement of L1/mm | 1.42 | 1.11-1.81 | 0.005 | 1.18 | 0.88-1.58 | 0.271 |

ICP: interproximal contact point; ABC: alveolar bone crest; CEJ: mesial cementoenamel junction; △IMPA: changes in the angle between the mandibular central incisor long axis and the mandibular plane before and after treatment; L1: mandibular central incisor

enamel reduction，IPR）与下颌中切牙区开放性龈楔状隙发生之间的关系。有文献指出IPR可以减少唇侧方向的倾斜程度，从而降低骨开窗的风险[16]，还可以改善牙齿形态为牙龈创建适当的附着区域[17]。Cuzin等[18]认为IPR可以解决牙齿大小的差异以实现最佳的咬合关系和排齐牙齿，解决拥挤问题并避免开放性龈楔状隙的发生。所以当发生开放性龈楔状隙时，可以采取少量IPR作为处理方法，并与压低牙齿等其他方法相结合，改善开放性龈楔状隙的发生[19]。

本研究Logistic回归分析结果显示附件数量与下颌中切牙区开放性龈楔状隙的发生有关，这可能是因为附件增加了矫正器与牙齿的贴合度和牙齿上施加力的表面积，提高了牙齿移动效率以及牙齿运动的复杂性[20-21]，附件类型也影响隐形矫治中牙齿移动的效率[22]。有研究显示附件数量与下中切牙和侧切牙唇侧骨开裂的发生呈正相关[23]，此外，附件的黏结也会降低患者口腔清洁效率，从而影响牙周组织增加开放性龈楔状隙的发生率[24]。

本研究表明近中切角间前后向距离与下颌中切牙区开放性龈楔状隙的发生呈显著相关。近中切角间前后向距离是与拥挤相关的变量，拥挤的牙齿排齐后可能会导致相邻牙根间角度增加、牙间乳头被拉伸、牙龈厚度减少等，增加了开放性龈楔状隙发生的风险。有研究显示下颌拥挤度每增加1 mm，发生开放性龈楔状隙的几率增加1.182倍[5]。Rashid等[25]也认为拥挤的严重程度与开放性龈楔状隙的发病率相关，且拥挤程度越大，开放性龈楔状隙的发生率越高。以上结果都表明前牙近中切角间前后向距离是开放性龈楔状隙发生的危险因素。

本研究与以往研究结论相似，认为邻接点至牙槽嵴顶间的距离以及相邻釉牙骨质界间的距离是开放性龈楔状隙形成的可能危险因素。Chen等[26]研究了微型种植体辅助快速腭扩弓后上颌中切牙牙间乳头高度的变化，发现前牙邻面接触点与牙槽嵴顶之间的距离是影响牙间乳头高度丧失的相关因素，同Tian等[27]的研究结果一致。Desai等[28]认为相邻根间水平距离增大，牙槽嵴顶与接触点之间距离的增加所产生的牙龈退缩将更为显著。本研究结果显示唇侧牙槽骨厚度不是开放性龈楔状隙发生的危险因素，这可能由于本研究只测量了未拔牙患者矫正结束时的唇侧牙槽骨厚度，并未选取多时间点测量。有研究显示正畸后期牙槽骨厚度与矫治前厚度几乎一致，正畸前期牙槽骨厚度减小，这是由于牙槽骨发生改建，先吸收后增生，改建存在延迟现象[29]，因此为获取良好的矫正效果，正畸医生在矫治过程中要实时观察牙周组织的改变。

对于正畸牙齿的移动方式与开放性龈楔状隙的发生之间的关系，目前还具有较多争议[11,30]。

不恰当的正畸牙齿移动作为一种医源性因素会引起牙龈退缩,压低量< 2 mm和唇侧倾斜< 5°是前牙不出现开放性龈楔状隙的警戒线[31]。有研究显示唇向倾斜移动可能会引起牙齿唇侧牙龈退缩,倾斜度每增加1°,牙龈退缩将增加约0.2 mm[32-33]。An等[34]通过回归分析发现,下颌切牙的压低会加重开放性龈楔状隙的严重程度,这可能与下前牙易沉积牙结石有关。本研究回归分析结果表明下颌中切牙唇倾度的改变,以及移动方式和距离不是开放性龈楔状隙的发生的危险因素,造成此结论可能与本研究选取的研究对象是未拔牙的成人患者有关,但下前牙压低量可能与开放性龈楔状隙的严重程度有关,符合以往研究结论。

开放性龈楔状隙的形成是多因素作用的结果,本研究纳入了多个变量,基于以上研究结果发现,附件数量、近中切角间前后向距离、牙邻接点至牙槽嵴顶间的距离以及相邻釉牙骨质界间的距离为矫治结束后出现下颌中切牙区开放性龈楔状隙的危险因素。但是由于回顾性研究的局限性,有待进一步扩大样本量进行研究,以深入探讨其潜在的影响因素。牙齿移动过程中咬合干扰[35]、咬合创伤[36]及后牙开䶗也是无托槽隐形矫治容易导致前牙牙龈退缩的重要因素,然而本研究只记录了矫治开始和结束时的牙龈状况,未关注矫正过程中牙龈的改变,未来可能需要进一步设计前瞻性纵向临床研究来阐明正畸治疗与开放性龈楔状隙之间的关系。

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