ORTHODONTIC WAVES XXX (2018) XXX–XXX

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/odw

Original article

Corrosion of metal orthodontic brackets and archwires caused by fluoride-containing products: Cytotoxicity, metal ion release and surface roughness

Tipanan Yanisarapan [a], *Pasutha Thunyakitpisal* [b], *Pintu-on Chantarawaratit* [a,*]

[a] *Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok 10330, Thailand*
[b] *Research Unit of Herbal Medicine and Natural Product for Dental Application, Department of Anatomy, Faculty of Dentistry, Chulalongkorn University, Bangkok 10330, Thailand*

ARTICLE INFO

Article history:
Received 12 October 2017
Received in revised form
10 January 2018
Accepted 2 February 2018
Available online xxx

Keywords:
Archwire
Bracket
Corrosion
Cytotoxicity
Fluoride
Ion release
Metal orthodontic appliance
Surface roughness

ABSTRACT

Purpose: The aims of this study were to determine the cytotoxicity, metal ion release and surface roughness of metal orthodontic appliances after immersion in different fluoride product solutions.

Materials and methods: Twelve sets of 20 brackets and four tubes were ligated with three types of archwires: stainless steel, nickel-titanium, and beta-titanium. The samples in each archwire group were divided into three subgroups and immersed in solutions of fluoride toothpaste, 1.23% acidulated phosphate fluoride (APF), or artificial saliva without fluoride as a control group. The immersion times were estimated from the recommended time of using each fluoride product for 3 months. The samples were immersed in cell culture medium for 7 days. Primary gingival fibroblast cell viability was determined by an MTT assay. Metal ion (nickel, chromium, iron, and molybdenum) release and surface roughness were measured by inductively coupled plasma mass spectroscopy and a noncontact optical 3-dimensional surface characterization and roughness measuring device, respectively. The bracket and wire surface morphology was observed using scanning electron microscopy. The data were analysed by Two-way ANOVA.

Results: In the APF groups, the four metal ion levels and surface roughness of the brackets and archwires significantly increased, while cell viability significantly decreased, especially in the TMA subgroup. The SEM results showed that the brackets and wires in the APF groups demonstrated more lines and grooves compared with the other groups.

Conclusion: Using APF gel during orthodontic treatment with fixed metal appliances should be avoided.

* *Corresponding author.*
E-mail address: cpintuon@chula.ac.th (P.-o. Chantarawaratit).
https://doi.org/10.1016/j.odw.2018.02.001

1. Introduction

Orthodontic brackets and archwires are commonly made of metal alloys, and are maintained in the oral cavity for several years, thus, their corrosion must be considered. Moreover, there are many factors in the oral environment that promote orthodontic metal appliance corrosion, such as temperature, saliva pH, fluoride, bacterial flora, enzyme activity, and proteins [1]. Corrosion compromises the mechanical properties of metal alloys by increasing surface roughness and decreasing mechanical strength [2,3].

The cytotoxicity of a corroded metal orthodontic appliance is an important issue. Corrosion releases metal ions into the oral cavity that are ingested into the gastrointestinal system. A previous cell culture study found that stainless steel brackets incubated in cell culture medium for 30 days released high concentrations of metal ions, such as titanium, chromium, manganese, nickel, and molybdenum [4]. Metal ion release can cause both local and systemic adverse biological effects on patients' health. Locally, the released ions may adversely affect the oral tissues by inhibiting enzyme or mitochondrial activity and damaging DNA, as has been demonstrated *in vitro* [4–6]. Moreover, chromium and nickel ions may induce type IV hypersensitivity [6]. Orthodontic patients have been reported to have two-fold more nickel allergy compared with non-orthodontic patients [7].

Fluoride products have been widely recommended for dental caries control, and fluoride toothpaste is almost universally recommended for tooth brushing [8]. Additionally, fluoride gel is commonly used, especially in high-risk caries patients, such as those undergoing orthodontic treatment [9,10]. However, sodium fluoride from fluoride-containing products reacts with hydrogen ions from bacterial products, resulting in the formation of hydrofluoric acid (HF) [11]. This acid dissolves the protective oxide layer on the surface of metal orthodontic components, resulting in bracket and archwire corrosion [11]. A previous study reported that stainless steel and nickel-titanium wires used with stainless steel brackets corroded when immersed in 1.23% acidulated phosphate fluoride (APF) [2]. This corrosion resulted in surface roughness and friction between the brackets and archwires, affecting the efficiency of orthodontic treatment [2,12]. Moreover, surface roughness is a predisposing factor for caries and gingivitis because it induces plaque accumulation on the appliances and adjacent tooth surfaces [13].

Few studies have evaluated the effects of fluoride on the corrosion of orthodontic metals [2,14]. To date, there is no study that has determined the amount of metal ion release, their biocompatibility, or the surface morphology and surface roughness of stainless steel brackets and different types of archwires, when patients use topical fluoride products.

The purpose of our study was to evaluate the metal ion release, cytotoxicity, surface morphology, and surface roughness of stainless steel brackets and three different types of archwires; stainless steel (SS), nickel-titanium (NT) and titanium molybdenum (TMA) exposed to fluoride toothpaste or APF gel.

2. Materials and methods

2.1. Sample preparation

The sample assembly and experimental protocol are shown in Fig. 1. Thirty-six sets of brackets and tubes were prepared to simulate full fixed orthodontic appliances of both dental arches. Each set included 20 brackets, four tubes (Tomy, Ortho M, Tokyo, Japan) with a slot size of 0.018 in., and two preformed archwires. The sample sets were divided into three groups of 0.016-in. × 0.022-preformed SS, NT and TMA archwires; (Ormco, Accord, Orange, CA). The compositions of the three archwire alloys are shown in Table 1 [15]. The archwires were ligated to the brackets by 0.010-in. ligature wires (Ormco, Accord, Orange, CA) to form bracket/archwire samples. Each sample was weighed using a semi-micro-analytical balance (NewClassic MS-S, Mettler Toledo, Greifensee, Switzerland).

2.2. Fluoride and control solutions

The samples were exposed to one of three media: artificial saliva (Table 2), toothpaste, or APF gel. The volume of the control medium was calculated from ISO10993-5 at 1 ml per 0.2 g of the sample weight [16]. The toothpaste medium was a mixture of sodium fluoride toothpaste (Colgate Total, Colgate-Palmolive, Thailand) and artificial saliva at a 1:4 (w/v) ratio. The APF medium was prepared by mixing 1.23% APF gel (Pascal International Inc., Bellevue, WA) and artificial saliva at a 1:1.4 (v/v) ratio.

The twelve samples in each archwire group were divided into three subgroups by media; control, toothpaste, and APF. The samples were immersed in media in an incubator shaker at 37 °C, 80 rpm, for a period based on the recommended 3-month clinical use time of each fluoride product:

1. Control groups (Con): 12 samples were immersed in artificial saliva without fluoride for 5 h 36 min, as calculated below.
2. Toothpaste groups (TP): 12 samples were immersed in toothpaste solution for 5 h 36 min, simulating the total recommended tooth-brushing time for 3 months, i.e., 2 min, twice a day [10],
3. APF groups (APF): 12 samples were immersed in APF solution for 4 min and dried for 30 min, simulating the recommended time of APF gel application, i.e., 4 min, once every 3–6 months [10].

The samples were cleaned with 100 ml deionized water and immersed in cell culture medium (Dulbecco's Modified Eagle's medium: DMEM), in the same volume calculated above, at 5 °C for 7 days. The culture medium was divided into two aliquots, one each for metal ion measurement and cytotoxicity testing.

2.3. Metal ion measurement

Plastic tubes (Corning, Sigma-Aldrich, St. Louis, MO.), 15 ml capacity, were cleaned by immersion in 10% nitric acid overnight and washed with deionized water. Three ml culture

Please cite this article in press as: T. Yanisarapan, et al., Corrosion of metal orthodontic brackets and archwires caused by fluoride-containing products: Cytotoxicity, metal ion release and surface roughness, Orthod Waves (2018), https://doi.org/10.1016/j.odw.2018.02.001